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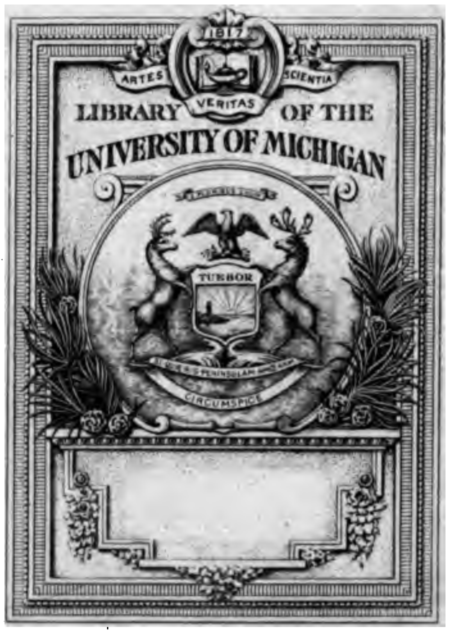

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BULLETIN

OF THE

UNITED STATES FISH COMMISSION.

VOL. XIII,

FOR

1893.

MARSHALL McDONALD, Commissioner.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1894.

PREFACE.

The World's Columbian Exposition was the cause of bringing together representatives of many departments of human industry from nearly every section of the globe. A very important feature of its organization was a World's Congress Auxiliary, of which Hon. C. C. Bonney was president. Through the medium of this bureau, and upon its invitation, a number of persons connected with the fishery interests availed themselves of the opportunity to organize a congress for the discussion of the various subjects relating thereto, which met October 16, 1893, and continued in session for four days, delegates from many countries being present. Its success far exceeded the anticipations of its promoters. Papers were read on various fishery topics, eliciting in many cases considerable debate. As was expected, the same subject gave rise to the expression of widely divergent views, particularly as to some phases of the commercial fisheries, which clearly demonstrated that a fair conclusion on any of the subjects discussed can be reached only after a careful consideration of all the views presented. Indeed, many earnest students of the fisheries are cautious in expressing positive convictions on some of the subjects in controversy, owing to inadequate knowledge on many points.

The papers here presented, being the views of representative men qualified by experience and study to speak upon the subjects treated, must necessarily be of great practical worth. In giving them in this form the U. S. Fish Commission does so with the idea of furnishing the general public much valuable information concerning the fishery industry, and not for the purpose of indorsing or disapproving the opinions expressed.

MARSHALL MCDONALD,
Commissioner.

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WORLD'S FISHERIES CONGRESS.

1.—REPORT OF THE SECRETARY OF THE GENERAL COMMITTEE.

Hon. MARSHALL McDONALD,
U. S. Commissioner of Fish and Fisheries:

SIR: The World's Congress Auxiliary of the World's Columbian Exposition of 1893, having extended an invitation for the assembling in Chicago, during the period of the Exposition, of persons interested in the various departments of human activity in all countries, a number of persons charged with duties, either directly or indirectly associated with the fisheries and fish-culture of the United States and foreign countries, concluded to utilize the opportunity thus presented by establishing a Fisheries Congress.

The preliminary meeting was held in Chicago on April 25, 1893, at which were present Hon. Marshall McDonald, U. S. Commissioner of Fish and Fisheries; Dr. G. Brown Goode, Assistant Secretary of the Smithsonian Institution, in charge of the U. S. National Museum; Prof. S. A. Forbes, director of the Illinois State Laboratory of Natural History, and Dr. Tarleton H. Bean, assistant in charge of the Division of Fish-culture of the U. S. Fish Commission and representative of the Commission at the World's Columbian Exposition.

On motion of Dr. Goode, Marshall McDonald was elected chairman and Dr. T. H. Bean secretary of the general committee on organization, Dr. Goode and Prof. Forbes constituting the other members of the committee present. Upon Dr. Goode's motion, seconded by Prof. Forbes, Mr. E. G. Blackford, of New York City, Capt. J. W. Collins, chief of the Department of Fish and Fisheries at the World's Columbian Exposition, Mr. R. E. Earll, and Mr. N. K. Fairbank were proposed as additional members of the general committee. A resolution was passed providing that three members should constitute a quorum for the transaction of business.

Many names of persons interested in the objects of the Congress were proposed for membership in the advisory council. The list included leaders in science, the fisheries, and fish-culture, in the United States and other countries.

The members of the general committee then outlined a provisional list of topics suitable for the occasion. The synopsis presented included:

The Administration of the Fisheries;
The Methods Employed in the Capture and Utilization of Fishery Products;
The Relation of Scientific Investigation to the Fisheries and Fish-culture;
A General Inquiry into the Subjects of Fish-culture and the Present Condition of the World's Fisheries.

The chairman appointed Dr. G. Brown Goode, Prof. S. A. Forbes, Capt. J. W. Collins, and Dr. T. H. Bean a committee to prepare a program of subjects appropriate for discussion; after which the committee adjourned, subject to the call of the chairman.

The president of the World's Congress Auxiliary (Hon. Charles C. Bonney) was advised of the preliminary steps taken by the general committee, and notices were sent to the persons named informing them of their selection by the World's Congress Auxiliary for the duties mentioned. Those who accepted the nomination to membership upon the general committee were Marshall McDonald, G. Brown Goode, S. A. Forbes, E. G. Blackford, Tarleton H. Bean, and R. E. Earll.

The second meeting of the general committee was held in the office of the U. S. Fish Commission exhibit at the World's Fair, June 19, 1893. At this meeting the secretary of the general committee was requested to draw up a preliminary circular defining the nature and aims of the Congress. A discussion of this circular was entered into and a draft of the main subjects was prepared by the committee.

The third meeting was held in the office of Mr. E. G. Blackford, Fulton Market, New York, July 30, 1893. At this meeting additions were made to the list of members of the advisory council, and the secretary was appointed chairman of a local committee of arrangements, with power to select two other members from the general committee, these members to make all of the necessary arrangements for the meetings of the Fisheries Congress. As the range of topics suggested a natural division into five sections, it was proposed to select chairmen for these groups of topics, and the following persons were nominated to act as chairmen:

Section 1: Fishery laws and regulations, Dr. William M. Hudson, Hartford, Conn.

Section 2: Science in relation to the fisheries and fish-culture, Dr. G. Brown Goode, Washington, D. C.

Section 3: Methods employed in the capture and utilization of fishery products, Dr. Hugh M. Smith, Washington, D. C.

Section 4: Fish-culture, Hon. E. G. Blackford, New York City.

Section 5: The World's fisheries, Dr. Tarleton H. Bean, Washington, D. C.

All of these persons accepted the nomination and assisted in the collection of papers to be read at the meetings. It was afterwards, however, found expedient to combine Sections 3 and 5, and Dr. Smith served as chairman during the session devoted to these groups. Meanwhile the president of the World's Congress Auxiliary assigned to the Fisheries Congress a place on the program of the agricultural congresses and fixed upon the week beginning October 16 as the period for holding the sessions.

The fourth meeting of the general committee was held in the office of the U. S. Fish Commission exhibit, Jackson Park, on September 24. There were present Messrs. E. G. Blackford, S. A. Forbes, and Tarleton H. Bean. Mr. Blackford acted as chairman of the meeting. Arrangements for the hour and date of the meetings of the Congress were assigned to the secretary of the general committee, but, upon motion of Prof. Forbes, an evening session was decided upon for October 17. The subject of a fish banquet was informally discussed and was deferred until the meeting of the local committee at the office of Mr. A. Booth, of Chicago, on Monday, September 25. Prof. Forbes was appointed a committee to make the arrangements for such meetings as might be necessary to be held in the World's Fair Grounds.

The fifth and last meeting of the committee took place in the office of the U. S. Fish Commission exhibit on Thursday, September 26. The following persons were present: E. G. Blackford, A. Booth, D. R. Cameron, R. E. Earll, George F. Kunz, and Tarleton H. Bean, several members of the advisory council having been invited to meet with the committee to complete preparations for the Congress. Mr. Blackford acted as chairman.

The secretary read the list of papers promised for the Congress. The arrangements for the meetings were announced by the chairman and the subject of the fish banquet was discussed by Messrs. Blackford, Booth, Cameron, Kunz, and others. The chairman appointed the following committee to arrange for the banquet, and the committee was given power to act: Messrs. A. Booth, D. R. Cameron, R. Edward Earll, George F. Kunz, and Tarleton H. Bean. The chairman was also requested to act with this committee and consented to do so. The committee on invitations, consisting of Messrs. Booth, Earll, and Bean, was then appointed. The question as to the time to be devoted to the reading and discussion of papers was considered, and it was decided to leave this matter to the control of the chairman of the Congress.

As soon as the general committee was regularly organized the following preliminary address was sent to members of the advisory council, and other persons whose coöperation in the work of the Congress was desired. This was accompanied by a letter from the chairman of the committee inviting participation in the objects of the Congress and contributions to the series of articles:

THE WORLD'S CONGRESS AUXILIARY OF THE WORLD'S COLUMBIAN EXPOSITION OF 1893.

President, Charles C. Bonney; Vice-President, Thomas B. Bryan; Treasurer, Lyman J. Gage;
Secretaries, Benj. Butterworth and Clarence E. Young.

DEPARTMENT OF AGRICULTURE.—GENERAL DIVISION OF FISH AND FISHERIES.

Preliminary Address of the General Committee on a Fisheries Congress in connection with the World's Columbian Exposition.

In accordance with the plans of the World's Congress Auxiliary of the World's Columbian Exposition, arrangements have been made for an International Congress of persons interested in fisheries and fish-culture at Chicago, commencing October 16, 1893.

The term fisheries, for the purposes of this circular, is intended to include every form of life in the waters of the globe which is now, or has been, the object of industry, considered in all its relations to associated life. Fish-culture is understood to refer to the increase and distribution of economic forms of aquatic life. Fisheries and fish-culture are intimately associated with various departments of science—historical, physical, social, and political—and it is proposed to discuss them with reference to such association.

Thus the deliberations of the Congress will cover a wide range of subjects, which may be suggested under the following subdivisions:

1. Fishery laws and administration of the fisheries, comprising: (*a*) state laws; (*b*) interstate regulations; (*c*) national laws; (*d*) international law and international equity.
2. The sciences in relation to fisheries and fish-culture: (*a*) biology; (*b*) physics; (*c*) chemistry; (*d*) geography; (*e*) climatology.
3. Methods of capture, utilization, and distribution of fishery products.
4. Fish-culture: (*a*) private; (*b*) public.
5. The world's fisheries.

The committee in this general way presents an outline of the proposed nature of the Congress, and suggests below a series of topics which it deems suitable for discussion. Additional themes will be furnished with the assistance of members of the advisory council, and are requested from persons who receive this circular.

1. FISHERY LAWS, ETC.

The necessity of placing oyster-planting grounds other than natural beds under private ownership and control, in order to secure the largest and most regular production.

Should government, state or national, farm the waters?

How shall we deal with the purse-seine and pound-net fisheries?

Why transportation companies should aid in the distribution of fish.

The utility and results of legislation for the ocean fisheries.

2. THE SCIENCES IN RELATION TO FISHERIES, ETC.

The scope, aims, methods, and apparatus of economic aquatic biology.

The system of life in waters.

The purpose, plans, and uses of a station for marine research. The obligation of government to maintain such stations.

The obligation of governments to prosecute marine research and deep-sea explorations

A program for a model lake survey.

A program for a model survey of a river system.

The migrations of fishes.

The distribution of economic fishes.

The aquarium; its installation and management.

3. METHODS OF CAPTURE, ETC.

Description of methods and apparatus employed in the fisheries.

Influence of methods upon abundance.

Improvements in fishing vessels and apparatus.

Economical value of marine products.

Preparation, care of, and manufacture of fishery products: (*a*) the market fishery; (*b*) refrigeration; (*c*) drying fish; (*d*) salting fish; (*e*) canning industry; (*f*) utilization of skins and other parts of marine objects—furs, whalebone, sounds, ambergris, oil, etc.; (*g*) fish guano.

Transportation of fishery objects and products.

The utilization of new and waste products of the fisheries.

The question of bait and bait preservation in the offshore fisheries.

4. FISH-CULTURE.

A review of fish-culture in Europe and in North America.

The scientific foundations of fish-culture.

The present state and principal defects of scientific fish-culture.

General conditions involved in stocking new and restocking depleted waters.

Comparison of methods employed in packing and transporting fish ova.

Cheaper and better food for rearing fish.

The conditions determining whether to plant impregnated eggs, fry, or fingerlings.

The methods and results of artificially breeding food for fish.

Comparison of methods in oyster-culture in the United States and in foreign countries.

The need of a government oyster-cultural station. What should be its general plan and arrangement; what it may be expected to accomplish in the way of example and instruction.

The relative value of artificial propagation, and regulation and protection in maintaining the lobster fisheries.

The necessity of affording proper instruction to students in fish-culture.

Fish-culture as applied to the maintenance or regeneration of the ocean fisheries.

Economic results of acclimatization of aquatic products.

5. THE WORLD'S FISHERIES.

Review of the world's fisheries.

- (*a*) The mollusk fisheries (squid, oyster, pearl, clam, abalones, scallop, periwinkles, snail, unios, etc.).
- (*b*) The sponge fishery.
- (*c*) The crustacean fishery (lobster, crab, shrimp, prawn, crayfish, etc.).
- (*d*) The amphibians and reptiles (frogs, turtles and terrapins, alligators, etc.).

(e) The mammals (whales, porpoises, seals, walruses, otters, etc.).

(f) The fishes (cod family, herring family, mackerel family, the *Sciænidæ*, the mullets, the salmon family, the perch-like fishes, the *Siluridæ*, the pikes, the carps, the sturgeons, the eels, sharks, skates, etc.).

Fishery statistics in general.

The relation of fisheries to civilization.

The relation of the fisheries to the navy and the merchant marine.

The fishermen; their physical and financial conditions and the means for their improvement.

The duty of the general government in the matter of a fisheries intelligence service.

The question of the desirability of establishing technical training schools for fishermen.

Fishermen's associations, unions, libraries, etc.

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Dr. Franz Hilgendorf, Berlin, Germany.
Prof. Ernst Haeckel, Jena, Germany.
Sir Thomas Brady, Dublin, Ireland.
Prof. A. C. Haddon, Dublin, Ireland.
Rev. W. A. Green, Dublin, Ireland.
Dr. Antonio Della Valle, Modena, Italy.
Prof. P. Doderlein, Palermo, Italy.
Dr. Anton Dohrn, Naples, Italy.
Commendatore Enrico Hillyer Giglioli, Florence, Italy.
Prof. A. Targioni Tozetti, Florence, Italy.
Dr. Decio Vinciguerra, Rome, Italy.
Dr. K. Mitsukuri, Tokio, Japan.
K. Ito, Hakodate, Japan.
C. Sasaki, Tokio, Japan.
Prof. Alfred Dugès, Guanajuato, Mexico.
Señor E. Chazari, Superintendent of Fisheries, Mexico.
Prof. A. A. W. Hubrecht, Utrecht, Netherlands.
Dr. P. P. C. Hoek, Helder, Netherlands.
Rev. M. Harvey, St. Johns, Newfoundland.
Sir Ambrose Shea, St. Johns, Newfoundland.
Prof. Edward Payson Ramsay, Commissioner of Fisheries, N. S. Wales, Sydney.
Prof. Geo. O. Sars, Christiania, Norway.
Prof. Robert Collet, Christiania, Norway.
A. Landmark, Christiania, Norway (Inspector Inland Fisheries).
S. A. Buch, Bergen, Norway.
Frederick M. Wallem, Norway.
Capt. G. M. Dannevig, Norway.
Dr. Nicolas Borodine, Fish Commissioner for Ural District, Constant, Uralsk, Russia.
Dr. Oscar von Grimm, St. Petersburg, Russia.
S. Herzenstein, St. Petersburg, Russia.
Prof. Ovsjannikoff, Imperial Academy, St. Petersburg, Russia.
Dr. Alexis Ostroumoff, Sebastopol, Russia.
C. Stacy Watson, Great Yarmouth, Scotland.
Prof. J. C. Ewart, Edinburgh, Scotland.
Prof. W. C. McIntosh, St. Andrews, Scotland.
Dr. John Murray, Edinburgh, Scotland.
Dr. Fulton, Sci. Secretary Fisheries Board, Edinburgh, Scotland.
Prof. E. E. Prince, Ottawa, Canada.
Sir J. G. Maitland, Howietoun, Scotland.
J. J. Armistead, Solway Fishery, Dumfries, Scotland.
Lieut. Col. F. G. Sota, Spain.
Dr. Rudolf Lundberg, Stockholm, Sweden.
Dr. Filip Trybom, Stockholm, Sweden.
Dr. A. H. Malm, Goteborg, Sweden.
Prof. F. A. Smitt, Stockholm, Sweden.
Dr. Axel W. Ljungman, Lilldal, Sweden.
Dr. F. A. Forel, Morges, Switzerland.
Dr. Carl Vogt, Geneva, Switzerland.
W. Saville-Kent, Hobart Town, Tasmania.

In view of the vast and widespread interests dependent upon the fisheries throughout the world and of the influence exerted upon the maintenance of fishery by rational fish-culture, the assistance and hearty coöperation of men in all countries to whom these subjects appeal is greatly desired. The advantages to be derived from the presence in Chicago of manifold sources of information and comparison, both from exhibits and from representative men, should be fully utilized, and will undoubtedly lead to substantial public benefit. The committee aims to secure by further correspondence addresses upon the foregoing and related subjects for presentation at the meetings of the Congress.

M. McDONALD, *Chairman,*
U. S. Commissioner Fish and Fisheries.
TARLETON H. BEAN, *Secretary.*
S. A. FORBES,
N. K. FAIRBANK,
DR. G. BROWN GOODE,
A. BOOTH,
EUGENE G. BLACKFORD,
R. EDWARD EARLL,
Committee of the World's Congress Auxiliary on a Fisheries Congress.

WORLD'S CONGRESS HEADQUARTERS,
Chicago, August, 1893.

LETTER OF THE CHAIRMAN OF THE GENERAL COMMITTEE.

U. S. COMMISSION OF FISH AND FISHERIES.

Arrangements have been made for an international Congress at Chicago, commencing October 16, 1893, of persons interested in fisheries and fish-culture, as announced in the preliminary circular of the general committee, a copy of which is inclosed herewith. It is the earnest desire of the committee that you will prepare an address upon one of the subjects suggested in the circular, or upon some other related topic within the scope of the occasion, and present it in person at one of the meetings of the Congress.

If you are unable to be present it is hoped that you will send to the chairman of this committee an address to be read at one of the regular meetings, advising him as early as practicable as to the title of the article, in order that a preliminary program of papers may be issued with little delay.

Very respectfully, yours,

MARSHALL McDONALD,
Chairman.

While the preparations for the Fisheries Congress were going on the commissioners of fish and game of the New England States decided to hold a conference in connection with the Commission of the United States at Chicago during the week fixed upon for the sessions of the Fisheries Congress. The United States Commissioner of Fish and Fisheries was invited to act as chairman of the conference, and, in pursuance of his duty, he appointed Mr. E. A. Brackett, of Winchester, Mass., chairman of a committee of organization. Commissioner McDonald sent out the following invitation to members of the State commissions:

U. S. COMMISSION OF FISH AND FISHERIES, *Washington, D. C.*

DEAR SIR: In compliance with the request of the commissioners of fisheries of the New England States, I have the honor to invite you to a conference of the United States and State commissioners, to be held at Chicago on the 18th of October, 1893. This date is fixed by reason of the fact that the World's Congress of the Fisheries will then be in session, and the commissioners will have the opportunity of also attending the sessions of this body and participating in the proceedings. It is desirable that topics which are to be brought up for discussion at the conference should be announced in advance, so that those desiring to participate in the discussions may have the opportunity for due consideration and preparation.

I shall be glad to have you indicate topics appropriate for discussion, sending the same to Mr. E. A. Brackett, commissioner of fisheries for Massachusetts, at Winchester, Mass., whom I have requested to act as chairman of the committee of organization of the conference, associating with him such other members of the State commissions as he may find most expedient.

Very respectfully,

MARSHALL McDONALD,
U. S. Commissioner of Fish and Fisheries.

Chairman Brackett appointed the following commissioners to act with him on the committee of organization of the conference, and invited them to meet at the office of the U. S. Fish Commission exhibit in Chicago on October 17:

E. W. Gould, Searsport, Me.; Jno. W. Titcomb, Rutland, Vt.; W. P. Andrus, Minneapolis, Minn.; Joseph D. Redding, San Francisco, Cal.; H. B. Vincent, McConnelsville, Ohio; N. C. Prickett, Ravenswood, W. Va.; S. M. Bronson, Connecticut; Dr. J. T. Wilkins, Bridgetown, Va.

His letter of invitation follows:

COMMONWEALTH OF MASSACHUSETTS.

{ Department of Fisheries and Game.—Commissioners: Edward A. Brackett, Winchester; Edward H. Lathrop, Springfield; Isaiah C. Young, Wellfleet. }

WINCHESTER, MASS., ———, *1893.*

DEAR SIR: In compliance with the request of U. S. Commissioner Marshall McDonald, I have consented to act as chairman of the committee on organization of the conference of commissioners to be held at Chicago, October 18, notice of which has, I understand, been sent to you. It will greatly assist in the organization to know who are to be at the meeting. Will you, therefore, kindly inform me whether you intend to be present?

Suggestions of topics for discussion should be sent to me as early as possible.

I have the honor to be, yours, truly,

E. A. BRACKETT.

Chairman Brackett also issued the following list of topics for consideration at the conference:

Dear Sir: I inclose a list of the topics thus far received for consideration at the Conference of Commissioners of Fisheries and Game, to be held at Chicago October 18. Doubtless many other subjects will be suggested. It is the desire of U. S. Commissioner McDonald that the conference should be a free and friendly discussion of all matters connected with the work of the commissions.

The future of Fish-culture on the Pacific Coast The Cod and Halibut Industries of the Pacific } Paper	Joseph D. Redding, California.
Advisability of placing Black Bass in streams with Trout	Wm. C. Murdock, California.
The Rise and Decline of the Fishing Industry of the Great Lakes	H. B. Vincent.
The Fishing Industry of Lake Erie, past and present	Col. C. M. Keyes, Ohio.
Interstate Laws for the better Protection of Fish and Game	T. J. Griggs, Iowa.
Protection, especially of the Large Game	W. P. Andrus, Iowa.
Best Methods of Protection—by volunteer or salaried service? Statutory limit as to length of Fish—whether best form of Protection or not	John W. Titcomb, Vermont.
In stocking Public Waters with Fish artificially hatched, at what age is it most desirable to plant them?	E. A. Brackett, Massachusetts.
The relation of the Government to the maintenance of Fisheries	Dr. Joel C. Parker, Michigan.
What Fish are most profitable for Pond Culture, for home use, in inland States?	N. C. Prickett, West Virginia.
Effect of Fish Pounds and Weirs on our present and prospective Food-fishes	Dr. J. T. Wilkins, Virginia.

E. A. Brackett,
Chairman Committee of Organization.

On October 6 the general committee began the distribution of its provisional program containing titles of addresses and papers which had been received at that time. A copy of the program follows:

CONGRESS ON FISH AND FISHERIES.

In accordance with the preliminary address of this committee a Congress of persons interested in the fisheries and fish-culture will be held under the auspices of the World's Congress Auxiliary, at the Art Palace, Michigan avenue and Adams street, Chicago, beginning October 16 and continuing until the program of addresses and papers is exhausted. A convention of fish commissioners of the various States will also be held in the same place, in association with the Fisheries Congress, on October 16.

The following provisional program contains the titles of addresses and papers which have, up to this time, been furnished to the committee to be read at the sessions of the Congress.

PROVISIONAL PROGRAM.

Interrelation of the General Government, the State, and the Individual: Dr. Joel C. Parker, Grand Rapids, Mich.

The Assimilation of the Fishery Laws of the Great Lakes: Dr. G. A. MacCallum, Fish Commissioner, Dunnville, Ontario, Canada.

The Decrease of Fish in American Waters and some of the Causes: Mr. A. M. Spangler, President Fish Protective Association, Philadelphia, Pa.

The Relation of Scientific Research to Economic Problems: Dr. G. Brown Goode, Director U. S. National Museum Washington.

Biological Research in relation to the Fisheries: Prof. J. A. Ryder, Professor of Comparative Embryology, University of Pennsylvania, Philadelphia.

The Investigation of Rivers and Lakes with reference to the Fish Environment: Dr. B. W. Evermann, U. S. Fish Commission, Washington, D. C.

Preliminary Account of the Plankton Investigation for the Michigan Fish Commission on Lake St. Clair: Prof. J. E. Reighard, Professor of Animal Morphology, University of Michigan, Ann Arbor.

The Origin of the Food of Marine Animals: Prof. W. K. Brooks, Johns Hopkins University, Baltimore, Md.

On the Food of the Menhaden: Prof. James I. Peck, Williams College, Williamstown, Mass.

On the Pelagic Fauna in Connection with Fish Growth: Prof. W. C. McIntosh, St. Andrews, Scotland.

Atmospheric and other Influences on the Migrations of Fishes: Mr. J. J. Armistead, Proprietor of Solway Fishery, Dumfries, Scotland.

The Correlation of Land and Water in relation to Food Supply and Agriculture: Prof. W. O. Atwater, Professor of Chemistry, Wesleyan University, Middletown, Conn.

Observations Concerning Fish Parasites: Prof. Edwin Linton, Washington and Jefferson College, Washington, Pa.

The Aquarium: Prof. S. A. Forbes, Director of State Laboratory of Natural History, Champaign, Ill.

Utilizing the Giant Kelp of the Northwest Coast: Mr. James G. Swan, Port Townsend, Wash.

Methods of securing Herrings, Smelt, and Sardines at Port Townsend: Mr. James G. Swan, Port Townsend, Wash.

The Sardine of Puget Sound, and the Methods of Preserving it in Oil: Mr. James G. Swan, Port Townsend, Wash.

A Review of Fish-culture in Europe and North America: Dr. Nicolas Borodine, Fish Commissioner, Uralsk, Russia.
On the Fishes which have been Developed at the Marine Laboratory, St. Andrews: Prof. W. C. McIntosh, St. Andrews, Scotland.
On the General Question of Fish Hatching (Marine): Prof. W. C. McIntosh, St. Andrews, Scotland.
History and Methods of Whitefish Culture: Mr. Frank N. Clark, U. S. Fish Commission, Northville, Mich.
The Culture of Sturgeon in the United States: Dr. Bashford Dean, Department of Biology, Columbia University, New York City.
Methods employed at Craig Brook in rearing Young Salmonoid Fishes: Mr. Charles G. Atkins, U. S. Fish Commission, East Orland, Me.
Propagation of Black Bass in Ponds: Mr. William F. Page, U. S. Fish Commission, Neosho, Mo.
The Past, Present, and Future of Oyster-Culture in Georgia: Dr. A. Oemler, Savannah, Ga.
The Methods of Deep-water Oyster-Culture: Henry C. Rowe, New Haven, Conn.
Habits and Development of the American Lobster, and their Bearing upon its Artificial Propagation: Dr. F. H. Herrick, Adelbert College, Cleveland, Ohio.
Fisheries of Japan: Mr. Sakaye Sawatari, Commissioner of Japanese Fisheries Society.
Fishing in British Guiana: Mr. J. J. Quelch, Commissioner of British Guiana.
The Fisheries of Canada: Hon. L. Z. Joncas, Quebec.
Statistics of the Fisheries of the United States: Dr. H. M. Smith, U. S. Fish Commission, Washington, D. C.
Fish Industries of the Pacific Coast: Mr. Joseph D. Redding, Fish Commissioner, San Francisco, Cal.
Fur Seals from an Economic Standpoint: Mr. J. Stanley-Brown, Washington, D. C.
The Exhibit of Pearls at the World's Columbian Exposition: Mr. George F. Kunz, Jackson Park, Chicago, Ill.
Foul Fish and Filth Fevers: Dr. J. Lawrence-Hamilton, Brighton, England.
A Plea for Fishery Folks' Technical Education: Dr. J. Lawrence-Hamilton, Brighton, England.

These papers will either be presented by the authors in person or will be read by title or abstract only, and it is expected that all of the articles will afterwards be published in full. After the reading of the addresses opportunity will be given for their formal discussion. The committee requests that persons who desire to send additional titles, or who require further information about the Congress, address the Secretary of the general committee, Dr. Tarleton H. Bean, U. S. Government Building, Jackson Park, Chicago.

Arrangements are now being completed for an international fish banquet for the members of the Congress, the State fish commissioners, and invited guests on the evening of October 17.

MARSHALL MCDONALD, *Chairman.*
TARLETON H. BEAN, *Secretary.*
S. A. FORBES,
A. BOOTH,
EUGENE G. BLACKFORD,
G. BROWN GOODE,
N. K. FAIRBANK,
R. EDWARD EARLL,
Committee of the World's Congress Auxiliary on a Congress on Fish and Fisheries.

WORLD'S CONGRESS HEADQUARTERS,
Chicago, October 1, 1893.

Titles of papers continued to arrive, and the final program was not ready for distribution until the sessions of the Congress were opened. The following is a complete list of the papers presented for reading and publication:

PROGRAM OF THE CONGRESS ON FISH AND FISHERIES.

SECTION 1.—FISHERY LAWS AND REGULATIONS. (Dr. William M. Hudson, chairman.)

Address of the Chairman of the General Committee: Hon. Marshall McDonald, U. S. Commissioner of Fish and Fisheries, Washington, D. C.
The Assimilation of the Fishery Laws of the Great Lakes: Dr. G. A. MacCallum, Fish Commissioner, Dunnville, Ontario, Canada.
The Decrease of Fish in American Waters and Some of the Causes: Mr. A. M. Spangler, President Fish Protective Association, Philadelphia, Pa.
The Sea and Coast Fisheries: Hon. Daniel T. Church, Tiverton, R. I.
Our Ocean Fishes and the Effect of Legislation Upon the Fisheries: Mr. J. M. K. Southwick, Fish Commissioner, Newport, R. I.
The Past, Present, and Future of Trout-Culture: Mr. W. L. Gilbert, Plymouth, Mass.

SECTION 2.—SCIENCE IN RELATION TO THE FISHERIES AND FISH-CULTURE.

(Dr. George Brown Goode, Chairman.)

The Relation of Scientific Research to Economic Problems: Dr. George Brown Goode, Director U. S. National Museum, Washington.

Biological Research in relation to the Fisheries: Prof. John A. Ryder, Professor of Comparative Embryology, University of Pennsylvania, Philadelphia.

On the Influence of Light on the Periodical Depth Migrations of Pelagic Animals: Dr. Jacques Loeb, University of Chicago, Chicago, Ill.

The Investigation of Rivers and Lakes with reference to the Fish Environment: Dr. Barton W. Evermann, U. S. Fish Commission, Washington, D. C.

Some Plankton Studies in the Great Lakes: Prof. J. E. Reighard, Professor of Animal Morphology, University of Michigan, Ann Arbor.

Habits and Development of the American Lobster, and their Bearing upon its Artificial Propagation: Dr. F. H. Herrick, Adelbert College, Cleveland, Ohio.

The Origin of the Food of Marine Animals: Prof. W. K. Brooks, Johns Hopkins University.

Atmospheric and other Influences on the Migrations of Fishes: Mr. J. J. Armistead, Proprietor of Solway Fishery, Dumfries, Scotland.

The Correlation of Land and Water in Relation to Food Supply and Agriculture: Prof. W. O. Atwater, Professor of Chemistry, Wesleyan University, Middletown, Conn.

Observations Concerning Fish Parasites: Prof. Edwin Linton, Washington and Jefferson College, Washington, Pa.

The Aquarium of the United States Fish Commission at the World's Columbian Exposition: Prof. S. A. Forbes, Director of State Laboratory of Natural History, Champaign, Ill.

Description of the Fresh and Salt Water Supply and Pumping Plants used for the Aquarium: I. S. K. Reeves, U. S. N.

Observations and Experiments on *Saprolegnia* infesting Fish: G. B. Clinton, University of Illinois.

Report on a Parasitic Protozoan observed on Fish in the Aquarium: C. W. Stiles, PH. D., Department of Agriculture, Washington, D. C.

On the Food of the Menhaden (Illustrations by lantern slides): Dr. James I. Peck, Williams College, Williamstown, Mass.

SECTION 3.—FISH-CULTURE. (Mr. Eugene G. Blackford, Chairman.)

Address of the Chairman, Eugene G. Blackford, 80 Fulton Market, New York City.

A Review of Fish-Culture in Europe and North America: Dr. Nicolas Borodine, Fish Commissioner, Uralsk, Russia.

Some Notes about American Fish-Culture: Dr. Oscar Nordqvist, Inspector of Fisheries, Helsingfors, Finland.

Fish-Culture in Michigan: Hoyt Post, Esq., Fish Commissioner, Detroit.

Methods Employed at Craig Brook in Rearing Young Salmonoid Fishes: Mr. Charles G. Atkins, U. S. Fish Commission, East Orland, Me.

History and Methods of Whitefish-Culture: Mr. F. N. Clark, U. S. Fish Commission, Northville, Mich.

Propagation of Black Bass in Ponds: Mr. William F. Page, U. S. Fish Commission, Neosho, Mo.

Notes on the Hatching of Sturgeon: Dr. Bashford Dean, Columbia University, New York City.

The Past, Present, and Future of the Oyster Industry of Georgia: Dr. A. Oemler, Savannah, Ga.

The Methods of Deep-water Oyster-Culture: Mr. Henry C. Rowe, New Haven, Conn.

What We Know About the Lobster: Mr. Fred Mather, Cold Spring Harbor, N. Y.

Breeding Natural Food Artificially for Young Fish Artificially Reared: Mr. A. N. Cheney, Editor Shooting and Fishing, Glens Falls, N. Y.

Fish-Cultural Investigations at the St. Andrews Marine Laboratory (under the Fishery Board for Scotland): Prof. W. C. McIntosh, M. D., LL. D., F. R. S., Member of the Fishery Board for Scotland.

Description of the Marine Hatchery at Dunbar, Scotland: Dr. T. Wemyss Fulton, F. R. S. E., Superintendent of Scientific Investigations, Fishery Board for Scotland.

SECTION 4.—THE COMMERCIAL FISHERIES. (Dr. Hugh M. Smith, Chairman.)

The Maintenance and Improvement of the American Fisheries: Dr. Hugh M. Smith, U. S. Fish Commission, Washington, D. C.

Foul Fish and Filth Fevers: Dr. J. Lawrence-Hamilton, Member Royal College of Surgeons (London); Licentiate Royal College of Physicians (Edinburgh); 30 Sussex Square, Brighton, England.

Reforms and Improvements suggested for the Fisheries of Great Britain and Ireland: Dr. J. Lawrence-Hamilton, etc., 30 Sussex Square, Brighton, England.

Fishing in British Guiana: Mr. J. J. Quelch, Commissioner of British Guiana.

The Fisheries of Canada: Hon. L. Z. Joncas, Quebec.

The Fishing Industry of Lake Erie, Past and Present: C. M. Keyes, Sandusky, Ohio.

The Fisheries of the Virginia Coast: Dr. J. T. Wilkins, Fish Commissioner of Virginia.

Notes on the Irish Mackerel Fisheries: Rev. W. S. Green, Office of Irish Fisheries, Dublin, Ireland.

The Southern Spring Mackerel Fishery of the United States: Dr. H. M. Smith, U. S. Fish Commission.

The Past and Future of the Fur Seal: Mr. J. Stanley-Brown, U. S. Geological Survey, Washington, D. C.

Notes on the Fisheries and Fishery Industries of Puget Sound: James G. Swan, Esq., Port Townsend, Jefferson County, Washington.

Fish Nets; Some Account of their Construction and the Application of their various Forms in the American Fisheries: Mr. C. H. Augur, New York City.

Statistics of the Fisheries of the United States: Dr. Hugh M. Smith, U. S. Fish Commission.

The Exhibit of Pearls at the World's Columbian Exposition: Mr. George F. Kunz, New York City.

The Fisheries of Japan: By the Bureau of Agriculture of Japan.

The formal sessions of the World's Fisheries Congress were opened in Hall 26 of the Memorial Art Palace, Chicago, on Monday morning, October 16, 1893. The opening address was made by the chairman of the Congress, Hon. Marshall McDonald. During the temporary delay of the chairman of the first section, Mr. L. D. Huntington, president of the New York Fish Commission, acted as chairman of the section.

Dr. G. A. MacCallum's article was the first paper read. After its conclusion Dr. Goode spoke as to the value of occasions when such papers are brought together.

Mr. A. M. Spangler, president of the Fish Protective Association of Eastern Pennsylvania, then read his essay on the decrease of fish.

He was followed by Mr. Daniel T. Church, of Tiverton, Rhode Island, with a paper on the seacoast fisheries. After the reading of Mr. Church's article it was discussed, along with the essay of Mr. Spangler, by the following members of the Congress: Mr. D. T. Church, Mr. E. G. Blackford, Mr. W. H. Bowman, Dr. Jas. I. Peck, Mr. A. Booth, Mr. Hoyt Post, Mr. L. D. Huntington, Hon. Marshall McDonald, and Mr. Fred Mather.

The second session of the Congress began at 10 a. m., October 17. The general chairman, Hon. Marshall McDonald, made the opening address, after which the chairman of the meeting, Dr. G. Brown Goode, followed with an address on the "Relation of Scientific Research to Economic Problems."

The first paper on the program, by Dr. Jacques Loeb, was entitled "On the Influence of Light on the Periodical Depth Migrations of Pelagic Animals." It was discussed by Dr. Herrick, Hon. Marshall McDonald, and Dr. Goode.

Prof. B. W. Evermann read an essay on the "Investigation of Rivers and Lakes with reference to the Fish Environment."

Prof. J. E. Reighard, of the University of Michigan, gave an oral preliminary account of the Plankton Investigations for the Michigan Fish Commission on Lake St. Clair. This paper was discussed by Prof. Evermann, Mr. Fred Mather, Dr. Goode, Mr. A. Booth, and Mr. W. H. Bowman. Mr. Mather's remarks related to the straining capacity of towing nets, and Mr. Booth spoke of the effects of whitefish planting.

The last paper on the program, read by Dr. F. H. Herrick, of Adelbert College, related to the "Habits and Development of the American Lobster and their Bearing upon its Artificial Propagation." The discussion of this paper was entered into by Dr. Hudson, Mr. Church, Mr. Mather, and Mr. A. W. Harvey, Fish Commissioner of Newfoundland. Mr. Church stated that many young lobsters are deliberately killed by lobstermen, who crush them on the gunwale of the boat. Mr. Harvey spoke of the good results of planting lobsters in Newfoundland, and stated that he expects to turn out 1,000,000 young lobsters next year.

The evening session began at 8:25 in Hall 4 of the Art Palace. At this session the speakers were introduced by Mr. Eugene G. Blackford. Mr. J. Stanley-Brown, of Washington, D. C., delivered a lecture on the "Past and Future of the Fur Seal," and was followed by Dr. James I. Peck, of Williams College, Williamstown, Mass., with an address on the "Food of the Menhaden." Mr. Blackford made some remarks suggested by the lecture of Dr. Peck. Both of the evening lectures were well illustrated by means of lantern slides, the lantern and the attendant having been kindly furnished to the Congress, without expense, by the McIntosh Battery and Optical Company, of Chicago.

On Wednesday, October 18, the general chairman introduced the chairman of the meeting, Dr. Hugh M. Smith, of Washington, D. C., who delivered an address on the "Maintenance of the Fisheries of the United States."

Mr. A. A. Adams, of the American Net and Twine Company, of New York City, read a paper on "Fish-Nets; some Account of their Construction, and the Application of their various Forms in the American Fisheries," by C. H. Augur.

Dr. H. M. Smith followed with a paper entitled "Statistics of the Fisheries of the United States."

A paper by Mr. James G. Swan, of Port Townsend, Wash., on the "Sardine of Puget Sound," was read by the secretary, Dr. Tarleton H. Bean.

An article on the "Spring Mackerel Fishery," by Dr. Hugh M. Smith, was then presented to the Congress. In the discussion which followed, Mr. Blackford, Mr. I. C. Young, of Brookline, Mass., and Commissioner McDonald took part.

Prof. W. O. Atwater, of Wesleyan University, of Middletown, Conn., closed the session with an address substituted for his paper on the program for the 18th, on the "Correlation of Land and Water to Food Supply and Agriculture."

The fourth session of the Congress opened at 10:30 a. m. on Thursday, October 19, Mr. E. G. Blackford presiding at the meeting.

After a brief address by the chairman, a portion of Dr. Oemler's paper on the "Past, Present, and Future of the Oyster Industry of Georgia" was read by Dr. Bean.

This was followed by the article of Mr. Henry C. Rowe, on the "Methods of Deep-water Oyster-Culture."

Dr. Hudson made some remarks on the ownership of oyster-grounds, the Connecticut system being cited as particularly favorable to the growth of the industry.

Mr. Booth spoke of the inconvenience of oyster-growing in Maryland and Virginia, because of the difficulty of acquiring titles to grounds by private parties. Mr. Swartz also engaged in the discussion, and Commissioner McDonald referred to the benefits arising from private ownership of certain grounds, into which part of the discussion Mr. W. H. Bowman and Mr. A. Booth also entered.

Mr. Fred Mather read an article entitled "What we Know about the Lobster." In the discussion of this paper Mr. Chase, Commissioner McDonald, and Mr. Huntington participated. Mr. Blackford and Mr. Mather also entered into it, and Dr. Hudson referred to the outrageous practice of killing young lobsters by fishermen.

The paper of Dr. Bashford Dean on the "Culture of Sturgeon in the United States" was read by Mr. Blackford.

The sessions of the Congress were closed on Thursday night with a fish banquet in the banquet hall of the New York State building in Jackson Park. This banquet was participated in by members of the Fisheries Congress, the Conference of State Commissioners of Fish and Game, and their invited guests. Hon. T. W. Palmer presided and delivered the opening address. The other speakers of the evening were Hon. Carter H. Harrison, mayor of Chicago; Messrs. Andrews, Bowman, and Breslin, of New York; Commissioner McDonald, Mr. J. J. Quelch, Commissioner of British Guiana, and Mr. John Foord, Secretary of the New York Commission to the World's Fair.

Following is a complete list of the members of the World's Fisheries Congress, including some members of the advisory council, whose names appear also in the preliminary address of the general committee:

LIST OF MEMBERS OF THE WORLD'S FISHERIES CONGRESS.

Mr. A. A. Adams, American Net and Twine Co., New York City.
Mr. W. P. Andrus, Minneapolis, Minn.
Mr. J. J. Armistead, Solway Fishery, Dumfries, Scotland.
Mr. Charles G. Atkins, East Orland, Me.
Prof. W. O. Atwater, Wesleyan University, Middletown, Conn.
Mr. C. H. Augur, American Net and Twine Co., New York City.
Dr. S. P. Bartlett, Quincy, Ill.
Dr. Tarleton H. Bean, Washington, D. C.
Mr. William Bird, Fish Commissioner, Fairmont, Minn.
Mr. A. Booth, Chicago, Ill.
Dr. Nicolas Borodine, Uralsk, Russia.
Mr. W. H. Bowman, Fish Commissioner, Rochester, N. Y.
Hon. E. G. Blackford, New York City.
Mr. E. A. Brackett, Fish Commissioner, Winchester, Mass.
Prof. W. K. Brooks, Johns Hopkins University, Baltimore, Md.
Mr. J. Stanley-Brown, Washington, D. C.
Mr. W. R. Callicotte, Fish Commissioner, Denver, Colo.
Mr. D. R. Cameron, Chicago, Ill.
Mr. E. A. Chase, Tacoma, Wash.
Mr. A. N. Cheney, Glens Falls, N. Y.
Mr. Daniel T. Church, Tiverton, R. I.
Mr. Frank N. Clark, Northville, Mich.
Mr. H. F. Cook, Beatrice, Nebr.
Dr. Bashford Dean, Columbia College, New York.
Mr. Edward P. Doyle, No. 53 Broadway, New York.
Mr. R. Edward Earll, Washington, D. C.
Dr. E. Ehrenbaum, Helgoland, Germany.
Prof. Barton W. Evermann, Washington, D. C.
Mr. E. J. M. Favallini.
Mr. Richard E. Follett, Lime Rock, Conn.
Prof. S. A. Forbes, Champaign, Ill.
Mr. H. A. Gill, Washington, D. C.
Dr. G. Brown Goode, Smithsonian Institution, Washington, D. C.
Rev. W. A. Green, Dublin Castle, Dublin, Ireland.
Mr. Charles S. Griffith, Port Richmond.
Mr. T. J. Griggs, Fish Commissioner, Spirit Lake, Iowa.
Mr. David G. Hackney, Fish Commissioner, Fort Plain, N. Y.
Mr. Edward Hamilton, New York.
Dr. J. Lawrence-Hamilton, No. 30 Sussex Square, Brighton, England.
Mr. Robert Hamilton, Greenwich, N. Y.
Mr. L. G. Harron, Washington, D. C.
Mr. A. W. Harvey, Fish Commissioner, St. Johns, Newfoundland.
Prof. Francis H. Herrick, Adelbert College, Cleveland, Ohio.
Dr. William M. Hudson, Hartford, Conn.
Mr. L. D. Huntington, Fish Commissioner, New Rochelle, N. Y.
Mr. L. D. Huntington, jr., New Rochelle, N. Y.
Dr. Ephraim Ingals.
Mr. Alex. Jones, Woods Holl, Mass.
Col. C. M. Keyes, Sandusky, Ohio.
Mr. George F. Kunz, New York City, N. Y.
Mr. G. W. Langford, Fish Commissioner, Havana, Ill.

LIST OF MEMBERS OF THE WORLD'S FISHERIES CONGRESS—Continued.

Maj. J. Fry Lawrence, Louisville, Ky.
Mr. R. E. Lewis, U. S. Fish Commission, Washington, D. C.
Prof. Edwin Linton, Washington and Jefferson College, Washington, Pa.
Dr. Jacques Loeb, University of Chicago, Chicago, Ill.
Dr. G. A. MacCallum, Fish and Game Commissioner, Dunnville, Ontario.
Hon. Marshall McDonald, U. S. Commissioner of Fish and Fisheries, Washington, D. C.
Mr. H. D. McGuire, Portland, Oregon.
Prof. W. C. McIntosh, St. Andrews, Scotland.
Mr. Fred Mather, Cold Spring Harbor, N. Y.
Mr. L. M. D. Minerbi, Rome, Italy.
Dr. A. Oemler, Savannah, Ga.
Mr. William F. Page, U. S. Fish Commission, Neosho, Mo.
Dr. J. C. Parker, Grand Rapids, Mich.
Dr. James I. Peck, Williams College, Williamstown, Mass.
Mr. Hoyt Post, Fish Commissioner, Detroit, Mich.
Mr. Anton Pregler, Irving Park, Cook County, Ill.
Mr. N. C. Prickett, Fish Commissioner, Ravenswood, W. Va.
Mr. J. J. Quelch, Commissioner of British Guiana.
Prof. J. E. Reighard, Ann Harbor, Mich.
Mr. W. de C. Ravenel, U. S. Fish Commission, Washington, D. C.
Mr. Henry C. Rowe, New Haven, Conn.
Prof. John A. Ryder, University of Pennsylvania, Philadelphia, Pa.
Mr. Frank R. Sammis, Stratford, Conn.
Mr. Sayake Sawatari, Commissioner of Japanese Fisheries Society.
Mr. J. M. Schaedler, Aspen, Colo.
Dr. Hugh M. Smith, U. S. Fish Commission, Washington, D. C.
James G. Swan, esq., Port Townsend, Wash.
Mr. Christian Swartz, Shellfish Commissioner, South Norwalk, Conn.
Mr. W. S. Timberlake, Fish Commissioner, St. Paul, Minn.
Mr. John W. Titcomb, Fish Commissioner, Rutland, Vt.
Mr. Chas. H. Townsend, U. S. Fish Commission, Washington, D. C.
Mr. H. B. Vincent, Fish Commissioner, McConnelsville, Ohio.
Mr. Samuel Wilder, Rochester, N. Y.
Dr. John T. Wilkins, jr., Fish Commissioner, Bridgetown, Va.
Mr. W. C. Williams, New York City.
Mr. I. C. Young, Brookline, Mass.

During the sessions of the Congress the State fish commissioners entered into preliminary arrangements looking to the permanence of their organization and the appointment of annual meetings. It is believed, also, that the proceedings of the Fisheries Congress will develop a permanent organization of persons interested in the fisheries and fish-culture, which will take the form of a national society devoted to the subjects whose discussion was so favorably inaugurated under the auspices of the World's Congress Auxiliary. The results accomplished would have been comparatively insignificant without the hearty coöperation of the members forming the general committee and the local committees of organization. The series of papers brought together for the Congress is one of the most valuable collections which has ever been presented, and their publication will undoubtedly accomplish beneficent results for the fisheries and the fish-culture of the world.

Very respectfully,

TARLETON H. BEAN,
Secretary.

2.—ADDRESS OF THE CHAIRMAN OF THE GENERAL COMMITTEE ON THE WORLD'S FISHERIES CONGRESS.

By MARSHALL McDONALD,*

United States Commissioner of Fish and Fisheries.

As the representative of the general committee intrusted by the president of the World's Congress Auxiliary with the organization and conduct of this Fisheries Congress, it becomes my pleasant duty—personally it is my grateful privilege—to extend to you, in behalf of the committee, a cordial welcome and to invite the representatives of foreign nations who may be here present and the State commissioners who are charged with the administration of State fishery interests to active and earnest participation in the discussion of the various questions, which will have forcible and skillful presentation in the papers to be read at the different sessions of the Congress. A like cordial invitation is extended to all who, by reason of their immediate and personal relations, their experience, or their knowledge of fishery matters, are interested in the objects for which this Congress convened.

The program of the proceedings which you have before you will indicate clearly the range and scope of the deliberations of the Congress, as well as the diversity and complexity of the various problems which necessarily arise in seeking a rational and fruitful administration of fishery interests.

By reference to the list of papers contained in the program you will find that no important question relating to the fisheries has been ignored or neglected.

The administration of the fisheries, the methods and the influence of methods on production, the relations of the fisheries to science and to economics, their conservation and regeneration by artificial methods, and their present status and conditions, all have careful and deliberate presentation from different standpoints.

These different addresses, and the discussion growing out of them, will, I trust, be fruitful in bringing about a consensus of opinion in reference to the important questions relating to the administration of the fisheries, and in reference to which there should be concurrence of views and concert of action to secure the results we are all striving for.

I am disposed to think that in this country we have relied too exclusively upon artificial propagation as a sole and adequate means for the maintenance of our fisheries. The artificial impregnation and hatching of fish ova and the planting of fry have been conducted on a stupendous scale. We have been disposed to measure results by quantity rather than by quality, to estimate our triumphs by volume rather than by potentiality. We have paid too little attention to the necessary conditions to be fulfilled in order to give the largest return for a given expenditure of effort and money.

The argument that underlies and justifies fish-cultural methods, and which has built up and liberally sustained our State and National Commissions, is that the percentage of survival under artificial methods is so largely increased that by hatching but a small proportion of the total egg supply in any given field we may equal or surpass the results from natural reproduction in the same area, even when nature's methods are not contravened and rendered abortive by the methods of the fisheries.

Our methods in this respect are the methods of the farmer. From an acre of ground he harvests 20 or 30, or, under the best conditions, 40 bushels of wheat. He sets aside 1 bushel for seed, and the rest he may safely exchange for the necessities, the comforts, or the conveniences of life. This 1 bushel, sown under proper conditions of tilth and fertility (either natural or supplied), is a sufficient guaranty of the future harvest.

It is the same in our fish-cultural operations. By our methods we give to a small percentage of fish ova the potentiality of the entire reproduction under unrestrained natural conditions.

In the same measure, therefore, as we enlarge the means for artificial propagation may we ease or release our restraints upon the commercial fisheries and permit a larger catch without apprehending a deterioration of our fishery resources.

We must not, however, be unmindful of the fact that the prosecution of the fisheries, without reasonable and necessary restraints, is sure in the end to make adequate reproduction by artificial methods impracticable by obstructing or shutting off the sources of egg supply. Protection, therefore, and reasonable regulations as to the times and methods of fisheries is just as essential for the maintenance of our fisheries as is the largest measure of artificial propagation. The two are intimately and essentially related and interdependent; each implies the other; both must concur and have equal consideration in devising a rational and fruitful administration of our fishery interests.

We should, I think, keep always in view that the object of public fish-culture is to assure the utmost utilization of the resources of our waters and to permit the largest production that can be accomplished without deterioration or impoverishment. We should insist upon whatever measures of protection or regulation may be found necessary to accomplish this end. On the other hand, we should be careful not to embarrass or harass the enterprises of our hardy and adventurous fishermen by restraints that are not clearly necessary to accomplish the end in view.

The general topic for this, the opening session of our Congress, relates to the administration of the fisheries, to the measures of protection and regulation that are necessary to increase or maintain the supply and to prevent deterioration. You will have presented to you the well-considered conclusions of men well qualified by experience and prominence to command your thoughtful consideration. Permit me to express the hope that our deliberations will bring about a consensus of opinion which will find expression hereafter in a code of fishery regulations which will be not only effective, but generally acceptable.

The gentleman who will preside over the sessions of the Congress devoted to the administration of the fisheries is well known to you personally or by reputation. He has been influentially and progressively identified with fish-cultural advances ever since the economics of the water have attracted public attention and interest. He is to-day at the head of the oyster commission of the State from which he comes, and is at once the author and administrator of the policy of the State in reference to its oyster-grounds. This policy has in ten years increased fourfold the oyster production of Connecticut waters.

3.—THE ASSIMILATION OF THE FISHERY LAWS OF THE GREAT LAKES.

By G. A. MacCALLUM, M. D.,
Fish Commissioner, Ontario, Canada.

The immense expanses of water known as the Great Lakes and situated between the United States and Canada, or more properly between the United States and Ontario, have been, since the earliest times, among the best fishing-grounds in the world; indeed, Lake Erie has been judged by competent observers as having been at one time probably the best-stocked fish area known. Owing, however, to careless, excessive, and wasteful fishing, that which at one time was thought to be an almost inexhaustible source of wholesome fish food is rapidly ceasing to be a profitable fishing-ground, and if the enterprise of the governments of the two nations constituting their boundaries had not endeavored to keep up their stock by propagation and planting, it is almost certain that the time would already have arrived when the supply of commercial fish derived from these Great Lakes would be very limited. In Canada students and observers of these fisheries have not been slow in attributing the rapid decline to the fact that few, if any, of the American States bordering on the Great Lakes, and under whose control the laws regulating the fisheries exist, have enacted a close season during which time the fish may be allowed to reach their natural spawning-beds to deposit their spawn as nature intended they should, this mode in former years having been found amply sufficient to keep those great bodies of water teeming with magnificent fish.

It can hardly be conceived that a nation so advanced in thought and all that pertains to the best laws of modern life as the United States should have thus far overlooked so important a factor in keeping up a supply of an article so valuable in the economy of the nation.

It may be stated without fear of contradiction that the United States are to-day doing a greater work in the tolerably new art of pisciculture than any other nation in the world, but why they should allow the main factor in the reproduction of fish life to be neglected is incomprehensible to many scientists. Take Lake Erie, for instance, and we will grant that the fishermen of the day have reduced their business to a fine art; they have, by close observation, defined the spawning and feeding grounds of the different fish, also the times or seasons when the different kinds of fish, through their instinct, migrate to those great breeding-grounds—migrate in myriads. Having determined this, is it not surprising that they should be allowed to spread out their engines of destruction and take in unlimited numbers fish—each representing thousands of its kind, if allowed to live and deposit its eggs as nature intended it should?

It may be true that fishermen and dealers will argue that it is only during the spawning season that these fish can be taken in paying quantities, but that is no consideration when the preservation of fish life for future generations is to be provided for. It certainly is high time that the different States bordering on the Great Lakes should enact laws providing a close season at least for the great commercial fish—the salmonidæ. In no other way can the inevitable be long delayed. Although artificial culture and planting of fry is one of the greatest works of the age, the restocking of these depleted waters can not be accomplished by these alone.

The U. S. Fish Commission in one of its recent valuable reports states that—

> In no other country in the world are there fewer regulations and restrictions in regard to the fisheries of the country, yet it would seem that, in view of the condition of the fisheries, some decided restrictions and regulations should be enforced if the industry is not to be abolished.

The same report says:

> There is, however, a plea for the interference of the Government in certain cases, in regard to the fisheries that belong to the rivers or are near the shore, and, thereby, more specially related to the adjacent Commonwealth. Nearly all civilized nations have looked with more or less care after their interior or river fisheries and quite a number of the States of the American Union have their own special enactments on this subject.

This is true of the States which border on the Great Lakes, but as regards the fish which form the staple of the great fisheries of the international waters—the salmonidæ, as the whitefish, salmon trout, and herring—they have little or no regulation or close season, as will be seen from the following synopsis of the laws of those States:

Wisconsin: No close season for salmon trout, whitefish or herring; and trout, pike, bass, and maskinonge may be taken and sold during spawning season from any other waters than the inland waters of the State. However, it is provided that whitefish, and salmon trout must be stripped when taken and the spawn and milt mixed in a pail and the mixture thrown overboard—a very inadequate provision.

Minnesota: No close season for salmon trout, whitefish, or pike; close season for herring from November 10 to December 10.

Illinois: Though situated on Lake Michigan and not on international waters, this State has no close season for the Great Lakes, but has a close season from July 1 to April 1, as regards seines for waters wholly within its boundaries.

Ohio: Close season from June 15 to September 15, but none for whitefish or trout, albeit they do not allow nets to be placed on the reefs in Lake Erie.

Pennsylvania: Close season for speckled trout and salmon from August 1 to April 1; also for lake trout from October 1 to January 1, and for bass, pike, and pickerel between January 1 and June 1; but this does not apply to Lake Erie, although no netting whatever is allowed within a mile and a half of the shore.

New York: Close season for salmon trout, landlocked salmon, and lake trout in inland waters from October 1 to March 1; also a close season for black bass, Oswego bass, maskinonge, and pickerel from January 1 to July 1. Besides other special laws for special waters, it will be observed that there is no close season established for either whitefish, salmon trout, or herring in Lake Erie.

Michigan: Close season for inland waters for the salmonidæ from September 1 to May 1, but no close season for whitefish, salmon trout, or herring in the Great Lakes.

Thus it will be seen that, while there are State laws regulating fishery interests of inland waters, none of them, with one or two exceptions, have any restrictions or regulations whatever pertaining to the great international waters which lave their shores and furnish so important an article of commerce. The fish are left to shift for themselves and to be at the mercy of large moneyed fishing companies, whose only interest and object is, of course, to make all the money they can out of the industry, regardless of the length of time it may last or of the interests of posterity. Now, if we turn to the country bounding these great lakes on the north and examine its laws for the protection and preservation of this most important and valuable industry we find that, founded upon the close observations of men appointed from time to time to study the habits of the different fish, certain close seasons, corresponding to the breeding season of each species, have been established, during which the fish may, unmolested, have access to their spawning-beds. Thus, for the most valuable commercial family, the salmonidæ, the month of November has been set aside, during which time they shall not be caught nor sold; for maskinonge and bass April 15 to June 15 is the close season; pickerel, April 15 to May 15.

These laws are carried out vigorously and are found to be in the interest not only of the fishermen but also of the masses. True, the Canadian fishermen do a good deal of grumbling in some localities where they can see their American cousins fishing during the whole time when they have to hang up their nets. It is human nature and not to be wondered at. They invariably assert that they would be perfectly content to abide by the laws, which they say they know to be reasonable and proper, if there were similar regulations on the United States shores; in a word, if there were an "assimilation" of the fishery laws of the Great Lakes.

Of course it is well known that there are difficulties in the way of accomplishing this uniformity of laws, inasmuch as in Canada the control of the international waters is vested in the Dominion Government, while with our neighbors the control is vested in the different States; at the same time no separate State can enter into a treaty with a foreign country—that right being reserved to the Federal Government; neither can Canada, which is a colony, form a treaty with another country, for by our Constitution that right is reserved to the British Government.

However, no one would say that the matter is impossible; indeed the agitation which has taken place within the last two years is already bearing fruit, for the Dominion Government and the United States Government have shown their appreciation of the work by appointing two experts to make inquiries upon all the subjects urged by us. At the risk of being considered egotistical, we claim the credit for the inception of this idea and of instituting this agitation by bringing into existence those conferences which have come to be known as the International Fish and Game Conferences, the history of which is as follows: In the autumn of 1890 I was intrusted by the Ontario Government with the presidency of the Ontario Fish and Game Commission, appointed to inquire into the condition of the fish and game of the Province and to suggest means for its propagation and preservation. We made extensive inquiries throughout the Province and then naturally turned to the great States to the south of us to inquire into the laws and regulations respecting these subjects and luckily found New York State codifying its fish and game laws. We first asked if we could confer with its commission, which was very courteously granted; in fact, the codification committee procured a delay in reporting, on purpose to confer with the Ontario commission, and a date was fixed for a meeting.

Then we conceived the idea of extending the representation at the meeting, and we wrote to the governors of the different States bordering on the Great Lakes asking that each one send a representative to meet with us to discuss the advisability of procuring a uniformity of the fish and game laws of the States and provinces bordering on the international waters. The idea was at once accepted and almost everyone promised to send a representative. We met in New York at the Fifth Avenue Hotel on October 12, 1891, Canada and several of the States being represented, the Federal Government also sending Dr. Hugh M. Smith, of the U. S. Fish Commission. A discussion of the situation took place and a committee was appointed, representing the bordering States, to meet at Rochester, November 10, 1891, where the subject of securing uniform legislation in the two countries was to be discussed, together with other interesting subjects. This was a very successful meeting, and the more the idea of uniform fishery laws for the Great Lakes was discussed and thought of the more it commended itself to those interested as being desirable.

The next of the international meetings was held in Hamilton, Ontario, December 9, 1891, and this meeting also was largely attended, and a great deal of interest was evinçed in the discussion of the assimilation of the fishery laws of the two countries. The last meeting was held in Detroit on December 21 and 22 of 1892. This was a very important meeting, and was largely attended by representatives from all the States interested, as well as Ontario. The Dominion commissioners, appointed to make inquiries concerning the Ontario fisheries, also attended and took part in the discussions, as did a number of large owners of fishery interests. The result of this meeting was that certain important resolutions were adopted. These were as follows:

1. All small fish, and those unfit for food of all kinds, when taken in nets should be replaced in the water where taken alive, and that fishermen should not be allowed to take such fish on shore nor expose them for sale.

2. That no string of pound nets used in the lakes shall extend more than 4 miles from shore.

3. That one-half part of all channels between islands and elsewhere where fish migrate to spawn shall be kept free from nets of all kinds at all seasons.

4. That all whitefish taken of less than 16 inches in length and all salmon trout less than 2 pounds in weight shall be immediately returned to the waters where taken and shall not be exposed for sale. That all herring less than 8 inches in length and all wall-eyed pike less than 12 inches in length shall be returned to the waters where taken and shall not be exposed for sale.

5. That the month of November in each year be made a close season in all the Great Lakes for whitefish, herring, and salmon or lake trout.

6. That in the judgment of this conference there should be a close season for black bass, and that such season should be between the 1st of April and the 15th of June, and all kinds of fishing, including spearing, should be prohibited in the close season.

Your committee would further recommend that all penalties fixed for violations of any laws that shall be enacted shall be made not only to apply to those who take fish, but also to all persons who buy, sell, transport, or have the same in possession.

It may be seen from this that some real work has been done by these international fish conferences in laying out what work is to be done in the future. One thing is admitted by all—that our joint fisheries in the Great Lakes are rapidly on the decline, and that it is absolutely necessary that some steps be taken, and at once, by those legislatures interested to prevent, by enacting judicious laws and regulations, the failure of this most valuable heritage. It is plain from the evidence of the best authorities that the same close season will apply to all parts of these great waters, as there is very little variation in the time of spawning of the salmonidæ, the most important commercial fish of the area. Canada is perfectly willing to abide by the close seasons, which are already embodied in her law, if the different States bordering on these waters will enact and enforce the same laws, or such as may be agreed upon, which must conduce to the improvement of the fisheries. It would add greatly to the prospect of securing such legislation if this large and influential Congress should see fit to recommend, by a suitable resolution, the adoption of the resolutions passed at the Detroit meeting December 21, 1892, and thus further the movement for procuring uniformity of the fishery laws of the Great Lakes.

4.—THE DECREASE OF FOOD-FISHES IN AMERICAN WATERS AND SOME OF THE CAUSES.

BY A. M. SPANGLER,

President of the Pennsylvania Fish Protective Association, Philadelphia, Pa.

In a country like ours, any question relating to the general increase or diminution of wholesome food, of whatever kind, possesses or should possess interest for all. Our food resources are so vast and so varied that we are apt to regard them as almost inexhaustible, and hence many are less careful of them, less disposed to be economical in the use of them, and more likely to indulge in their abuse than were they more limited. Under the influence of such belief, our great forests are rapidly disappearing, millions of acres of once fertile lands have been cropped to impoverishment and turned out to await nature's recuperative influences; the buffaloes, once almost countless in numbers, have been practically exterminated; game animals and birds are steadily becoming more and more scarce, and many other of our natural resources have either been completely exhausted or greatly diminished by the belief in their inexhaustibility, or rather by the wastefulness and prodigality which, unfortunately, are to be classed among our national characteristics.

Among the many sources of wholesome food supply that have suffered, that of edible fish may be mentioned as specially prominent. While, to a great many, such an assertion would seem to lack verification, it is readily susceptible of demonstration; "confirmations, strong as proofs of holy writ," abounding in every direction.

Taking a map of the United States and noting our many majestic rivers, some of the largest in the world; the thousands of lesser magnitude and their innumerable minor tributaries, all capable of maintaining an immense amount of fish life; our chain of unrivaled lakes, equaling seas in area, with the many others of lesser note, and our thousands of miles of sea, gulf, and bay coasts, it may well seem incomprehensible, to those who have never given the subject serious thought, that with such extensive and varied waters there could be a possibility, even, of a scarcity of food-fish, either present or prospective. What adds to the incomprehensibility is the fact that within the memory of many now living, those streams, lakes, and coasts, almost without exception, teemed with food-fishes. Some of them are still prolific in that respect, but it is a deplorable truth that a very large proportion of them—those inland especially—have been either almost entirely depleted, or their productiveness so diminished as to practically amount to depopulation. If reliable statistics of the fish products of American waters fifty years ago were procurable, and compared with accurate statistics of the same waters to-day, the discrepancy would be startling.

That this alarming condition of our fishery resources has not been permitted to escape the attention of some of our more thoughtful people is evidenced by the fact that every State and Territory having any such resources has enacted laws for their protection and preservation, and twenty-one of them have one or more hatchery stations for the purpose of providing, by artificial means, young fish for the restocking of the depleted streams. These well-meant endeavors to arrest further diminution have, unfortunately, been only partially successful. This failure has been largely disappointing, for great results were expected from the carefully framed and very stringent statutes, as well as from the distribution of millions of young fish annually from the State hatcheries and from the national hatcheries under the control of the U. S. Fish Commission. Those hatcheries, national and State, have, under competent supervision faithfully and effectively carried on the work of artificial propagation, and their products have been judiciously used in restocking.

An idea of the extent of their operations will be gleaned from the following statistics of the propagating and distributing operations of the hatcheries of the State of Pennsylvania:

Species.	1890.	1891.	1892.
Shad	16,303,000	8,457,000	9,000,000
Brook trout	2,694,900	2,508,000	3,200,000
Salmon	94,000	....	300,000
Lake trout	168,000	196,500	175,000
Landlocked salmon	49,000	170,400	....
Black bass	840	3,895	6,000
Carp	4,525	5,679	6,000
Grass bass	....	1,325	2,000
Whitefish	10,100,000	11,770,000	30,000,000
Wall-eyed pike	13,545,000	40,600,000	65,000,000
California trout	508,600	523,500	522,000
Total	43,467,865	64,236,299	108,211,000

In connection with the foregoing statistics it may be stated that the product of the Delaware River increased from $80,000 in 1881 to over $500,000 in 1891. The value of the fishery production in Erie, the only lake fishery port of Pennsylvania, increased from $65,000 in 1885, at which time the whitefish hatchery was first started, to $500,000 in 1892. It is therefore clear that the failure referred to can not be attributed to remissness on the part of those having supervision of the hatcheries, though probably the output and distribution from those in Pennsylvania were larger than those of most of the other States.

To what cause or causes, then, are to be charged this nonfulfillment of expectation in regard to the results of such extensive propagation and restocking? Except in a few cases, we have nothing to indicate that there has been any marked increase of fish products or that the generally prevailing decrease has received any material check.

I propose now to briefly consider some of the many causes that have contributed, in a greater or less degree, to the reduction of the food-fish supply, beginning with those that have served most largely to render the fishery laws so nearly nugatory.

First among them, is the widespread lack of comprehension of the vastness of the fishery interests of this country—their real money value. The long-continued and still-prevailing barrenness of so many of our waters is regarded by the majority as a natural result, something to be accepted as inevitable and therefore remediless. This idea is especially prevalent among those of the present generation who, having never been familiar with the former prolificness and having never given thoughtful consideration to the subjects of artificial breeding and judicious restocking with subsequent protection, conclude that attempts at replenishment will prove futile. Having never known what is meant by fresh-fish plentifulness, they believe, or profess to believe, that money and effort spent for food-fish increase are simply money and effort wasted. They fail to comprehend the possibility of checking the decrease and of supplementing it with such an increment as will repopulate and restore productiveness, regarding it as a chimera. They have failed to grasp the idea that such restoration would add millions to the value of the country's resources and enable themselves and thousands of others, who have never known the luxury of partaking of fish taken from home waters, an opportunity for the enjoyment of such a treat.

Another very prevalent idea is, that the fish in public waters are the inherent property of the people, and may be taken at all seasons, wherever found and by whatever means. Fish protective laws are therefore naturally regarded by persons holding those opinions as positive infractions of popular rights, and as such, not only entitled to no respect, but should be resisted. To arrest a violator of them is looked upon as an outrage, and the officers of the law who cause such arrests are considered tyrants. Although it is the sworn duty of wardens, magistrates, and constables to have all offenders against fishery statutes brought to justice and punished, it needs not the saying that such sworn duties are rarely performed and that infractions being thus winked at by the authorities, the laws are brought into contempt.

Pollution of streams.—Another and a very prominent cause is the pollution of streams. Fish of all other living creatures have a detestation of impure water. It is the element in which they live and move and have their being. In the order of nature the water in which a fish is brought into existence is adapted to that fish's life. To assume any other condition of things would be an impeachment of the wisdom of the Creator. This, of course, applies to waters in their original condition, before civilization with its many contaminating influences intruded upon them. Naturally, therefore, when the sawdust from sawmills, the refuse from gas works and tanneries, the sewage from cities and towns, the deleterious drainage from manufactories, the pumpings from mines, etc., are deposited in or allowed to flow into streams, the result must either be the poisoning of the fish or the driving of them to more congenial waters, and the consequent depletion of those streams in which they would have lived and multiplied had they been permitted to do so without molestation.

Almost without exception the fishery laws of the States are emphatic in their prohibition of such contamination, but it is a fact established beyond all controversy that the instances in which the prohibition has been respected have been very rare indeed. Instead of regarding the water-courses as sources of health to human beings as well as to fish, they are deemed fit places of deposit for noisome and noxious materials of whatever kind that can be most conveniently disposed of through their agency.

Dams.—The erection of dams in streams frequented in their season by anadromous fishes has been generally exterminative of such fishes in the waters above such obstructions. A great many of the dams now in existence were built years prior to the enactment of fishery laws prohibiting such structures, except with a certain proviso. That proviso is, that the owners of dams that obstruct the ascent of fish shall place in each a fishway or fishways, so constructed as to afford ready passageway for anadromous and other fishes, whose habits incline them to ascend to the upper waters of the stream. The penalty for the violation of this statute is heavy, but like so many of the other fishery laws, its commands are more honored in the breach than in the observance.

The hurtful influences of these obstructions, where the law in regard to them is not respected, can readily be imagined. Even where there is compliance the compensation is generally only partial. A practical illustration of this is found in the Susquehanna River, which once abounded for several hundred miles of its length with shad, which for size and quality were unsurpassed. A dam was erected across that river at the town of Columbia, and thereafter the presence of shad in the waters above it became almost unknown. Prior to its erection your speaker saw more shad taken a mile above its location at a single haul of a seine than were afterward caught in the river northward in any entire season. This condition of things prevailed until the State fishery commissioners, some six or seven years ago, ordered the placing of several of the latest improved fishways in the dam. Since then some shad have been taken in the upper waters of the river, but it is questionable whether, even with these added facilities for the ascent of shad, the annual product has been materially increased, though better results are confidently anticipated; but there is little room for hoping that the former noted fecundity of the Susquehanna will ever be restored.

Fish baskets.—In the Delaware and Susquehanna rivers, and in nearly all of their principal tributaries and doubtless in many other rivers of rapid flow, fish baskets have been and still are to be found, than which it is impossible to conceive of any device more destructive to anadromous and migratory fishes. Through the energetic efforts of the Pennsylvania State fishery commissioners, they have been very nearly exterminated in the first of the two rivers named. Those baskets with their diverging wing walls, which obstruct the progress of the young fish seaward, compel them to seek passage at the point where the walls converge and where the basket is placed. Instinctively, the fish press onward and are often taken by thousands in the deadly trap. Instances have been known in the upper Delaware, where so many young shad were intercepted in fish baskets—of course, perishing there—that farmers hauled them away by wagon loads, using them for fertilizing purposes on their fields.

It has been estimated that before the interference of the State authorities as many young shad were destroyed through the agency of fish baskets each season as twice equaled the entire catch of mature shad in the Delaware.

Fyke or hoop nets.—Scarcely less destructive is the fyke net, which corresponds in character and intent with the fish basket, but because of the shortness of its wings is adapted only to smaller streams. Placed at the mouth or in the narrow channels of minor streams, it commands the entire passageway, and of course captures everything in the shape of a fish that attempts a descent.

The fyke net, like the fish basket, is strictly prohibited by law, but being portable it is readily placed in position at convenient times, and as readily removed and hidden away, if there is reason to anticipate a visit from any of the authorities. Detection, even if intended, is therefore difficult.

Betterton, at the mouth of the Sassafras River, on the eastern shore of Maryland, a few years ago was celebrated for the size, quality, and quantity of its white perch.

Four or five hundred, aggregating nearly as many pounds, were not an unusual single day's catch for two hook-and-line fishermen, but the fyke was introduced by the commercial fisherman, and to-day the man is lucky who succeeds in capturing two or three dozen of less than half a pound weight each. The glory of Betterton has departed.

A natural supposition would be, that men who earn their living by fishing would, on the score of self-interest alone, endeavor by all means in their power to prevent the fish products of the waters in which they ply their vocation from decrease. Generally speaking, the reverse of this is the case. In the immediate vicinity of the Betterton waters, perch used to be taken in small-meshed seines in large quantities, thousands of other fish, and especially young perch of unsalable size, being captured with them. Instead of being returned to the water, as they should and readily could have been, those unmerchantable fish were dumped upon the beach to die; furnishing tempting feasts from day to day to hundreds of hungry buzzards. These facts are given for the purpose of illustrating some of the many fish-exterminating methods practiced in thousands of places.

Explosives.—Another illegal, unnatural, and most indefensible method of killing fish is by the use of explosives, such as dynamite, giant power, etc. The placing and exploding of a dynamite cartridge in a pool of water means not only the killing of the larger fish, but not unfrequently of hundreds, sometimes thousands, of smaller ones. The dead fish rise to the surface, the larger ones being secured while the much greater number of smaller ones are borne away by the current. This reprehensible way of killing fish receives special mention in the restrictive laws of nearly every State; but dynamite cartridges and other explosives are so readily obtained now, so easily hidden from observation, and require such little preparation for their illicit use, that it is almost impossible to detect the guilty parties; therefore their employment for fish-killing purposes is much greater than is generally supposed.

The foregoing are some of the leading causes of the decrease of food-fishes in American fresh waters. There are numerous others of minor importance individually, but in their aggregate producing a vast amount of injury to fish life. Among them may be named the little respect which is paid by hook-and-line fishermen to the "close times"—the season when the fishes to which they specifically apply do their spawning. It is a fact, not as generally understood as it should be, that fishes of certain kinds, possibly all, when in a gravid condition take the bait much more readily than at any other period, and much more readily than the males. An adult female taken at such a time means the absolute destruction of from five hundred to one thousand germs of fish life; in some varieties, many more. How many gravid fish are taken every year can not of course be even conjectured, but from the number of poachers the total must run into a great many hundreds of thousands. This is the more to be deplored for the reason that the killed germs would have been naturally spawned and, through the instinct of the parent fishes, in localities better suited to the wants of the young fish and where they would have better protection and thrive better than artificially propagated fry, planted in waters assumed to be suitable, but which in fact may be the least adapted to their safety and growth.

The "pot hunter" is another deadly enemy to fish increase, as he counts all as fish his hook captures, whether they be fingerlings or pound weights. Instead of returning to the waters the small and worthless fish, he gives them a place in his creel in order that the count of his catch may be swelled to its utmost proportions. Such small ambition possesses many who would like to be deemed sportsmen, but whose rightful designation is "pot hunters."

Is it remarkable, then, in view of the many causes inimical to fish life that have been named, together with the still more extended catalogue of minor ones, that there has been a constant decrease of food-fishes in our inland waters, resulting in many cases in entire extermination?

SALT-WATER FISHES.

Turning from fresh-water to salt-water fishes, it is a question with many—some of them scientists of the highest repute, who have given the subject attention—whether there has been a decided diminution. However that may be, there are some facts, serving to show a temporary decrease at least, that merit consideration.

It is well known that migratory fishes—the herring and the mackerel for instance—suddenly appear or disappear at various points and intervals along the coasts, the causes of their appearance and disappearance alike lacking satisfactory explanation, some observers attributing the latter to continued tempestuous weather, others to the temperature of the water; but there is, I believe, no general agreement on the subject.

There are other varieties of coast fishes whose sudden comings are as mysterious as those of the herring or the mackerel, but whose departure is more gradual, and whose first plentifulness is not repeated in the subsequent year. Some twenty years ago immense multitudes of croakers suddenly swarmed along the coast of New Jersey. Although constant residents of near Southern waters, they were entire strangers to the oldest Jersey fishermen. What specific influences caused their presence in such countless numbers has not yet been explained. They were readily taken in any desired quantities with hook and line. They reappeared the following summer, but in sensibly diminished numbers, the diminution continuing from year to year, until to-day they are only occasionally captured. The cause of their gradual disappearance is as much a mystery as their sudden first arrival.

Squeteague or Weakfish.—Thirty or forty years ago the coast of New Jersey and its estuaries fairly teemed with squeteague or weakfish, but year by year their numbers have been steadily decreasing. There was a time, which extended through a number of years, when such a thing as scarcity of that favorite fish was unknown. The decline was specially noticeable last summer. A season of like scarcity is not remembered. Very few were taken in the estuaries, save in May, when they appeared in sparse numbers. A large proportion of those taken were captured in pound nets, weirs, and with seines, the majority of them being in a gravid condition. It was specially noticeable that the spawners eagerly took the bait offered them by hook-and-line fishermen, the males persistently refusing it.

That the killing of so many gravid fish thus early in the season for years previous had the effect of curtailing their numbers in subsequent seasons can not be questioned; but the curtailment was not sufficient to account for their steadily increasing scarcity. That it was a contributory cause must be admitted, and for that reason restrictions upon early spring fishing for them should be made part of the laws of New Jersey.

By some close observers last season's decline was attributed to the attacks of the bluefish, which no doubt had something to do with it, but that they were a principal cause is refuted by the fact that, during the period referred to, bluefish had decreased in about the same ratio. The almost entire absence of squeteague in the estuaries, their usual haunts until ready to migrate southward, is thought by some to have been due to the scarcity of their usual food supply, resulting from the intensely cold weather of the previous winter, and there is some reason in the opinion. But, as will presently be shown, there are other deeper-seated and farther-reaching causes.

Bluefish.—About sixty years ago, after a long absence, bluefish appeared in great schools along the Jersey coast. Then, as ever, they displayed the same insatiable voracity that has earned for them the appropriate designation of "unmitigated butchers." They increased in numbers with each succeeding season until about twenty years ago, when their plentifulness seemed to have reached its climax. It is on record, about that time, that in a single day one fisherman, handling three lines, caught 265 in Barnegat Bay; the day following, 261. It was not unusual for a party of two or three to take as many hundred in six or eight hours fishing. But, like the squeteague, they have steadily lost numerical strength. They are rarely seen now in Barnegat or any other of the bays on the coast. More of them were taken in a single season then than have been caught during the whole of the past ten years.

It would be hazarding little to assert that the number of bluefish on the coast for the past decade, as compared with that of twenty years ago, is ten to one in favor of the latter. Why this remarkable decrease? It has certainly not resulted from trolling hooks, nor from pound nets or weirs. It can not be reasonably charged to a lack of food, as the bluefish is such an expert hunter and such an indiscriminate feeder that even though its menhaden resources have been largely reduced, there are other sources of supply upon which it can draw, the kind or quality being seemingly of trivial importance, provided there is enough. Naturally, less aggressive food-fishes are prominent among those that suffer from its attacks, and here we have another contributing cause to the prevailing scarcity of the edibles.

The Menhaden.—The menhaden can not properly be classed among the food-fishes, though there are some that give them a place at their tables. They, however, play such a conspicuous part in the subject under consideration that they demand special attention. A prominent writer on ichthyology says of them:

> It is hard to surmise the menhaden's place in nature; swarming in waters in countless myriads; swimming in closely packed unwieldy masses, helpless as flocks of sheep, near to the surface and at the mercy of every enemy; destitute of means of defense or of offense, their mission is unmistakably to be eaten.

That paragraph was written some ten years or more ago, and is as true in every essential, save two, to-day as when it was penned. One of the exceptions is that of the "countless myriads." There are still great numbers of menhaden along the coast, but few compared with their former extraordinary abundance. The second exception is that "their mission is unmistakably to be eaten." While they are still the helpless prey of all the larger carnivorous fishes, another use has been found for them. They have formed the basis for a great industry. Millions of capital are invested in it, and, like many other American enterprises, it has been and is being prosecuted with such energy that a few years more of like effort will warrant the assertion that an approximation to extermination will be the result. Already the decrease is so marked that a number of the vessels employed have been withdrawn, the scarcity this season having rendered their further use unprofitable. This diminution has not been the result of one of those sudden and inexplicable fluctuations that characterize the movements of some of the migratory fishes, but, as will presently be shown by reliable statistics, has been a natural sequence to the unrelenting warfare waged upon them.

No other industry of the country has evoked a greater amount of unsparing condemnation. Public indignation has been righteously arrayed against it, though up to this time it has not taken on the concentrated form essential to a proper recognition of the abuse. A convention of representative men from several of the seaboard States has been called by a large number of prominent citizens of New York, for the purpose of considering the cause or causes of edible coast fish scarcity. What will be the outcome of that convention remains to be seen, but the fact is noteworthy that it will be the first regularly combined movement having for its object the correction of an undeniable evil.

Ordinary familiarity with the subject and a little thoughtful consideration will convince every unprejudiced mind that the time for the correction of this great public wrong has come, and that further delay in regard to the righting of it can hardly be looked upon as less than criminal.

The great original abundance of the menhaden is one of those wise provisions of the Creator for the maintenance of certain kinds of edible fish life. The shark, the swordfish, bayonet-fish, and other of the larger "corsairs of the sea" indigenous to the Atlantic coast, satisfy their ravenous appetites by indiscriminately slaughtering and devouring menhaden and, when opportunity offers, edible fish also. Why those large carnivoræ are thus provided for, and what are their special uses, are questions that need not be considered now. It would be ridiculous, nay, almost sacrilegious, to assume that each one has not a mission to perform, whatever that mission may be. Then again, the larger of the carnivorous food-fishes, as the striped bass, squeteague, bluefish, pollock, cod, bonito, and others, are the deadly enemies of the menhaden, feeding mainly upon them, in their season. These menhaden-eaters, finding their natural food supply diminished, prey upon each other, the stronger and more agile overpowering the weaker, and all of them devouring the smaller edible varieties when opportunity offers.

When the number and voracity of the larger carnivoræ of the coast are considered, the amount of food required to support them and the readiness with which they capture it, the number of fish destroyed by them in consequence of the increasing scarcity of menhaden can best be understood by the steadily decreasing edible coast fishes. The opinion of the writer already quoted, that the mission of the menhaden is "unmistakably to be eaten," is undoubtedly correct, just as would be the declaration that the mission of the carnivoræ of the sea are to be the eaters. But for the carnivoræ, the sea would have long since been a vast pest-pool, so great is the fecundity of the menhaden. They, the carnivoræ, devour so many of them that such injurious multiplication is prevented, and food-fish protected from their deadly assaults. But, when menhaden fishermen interpose with their purse nets, nature's equilibrium is destroyed. If it be asked why the menhaden did not multiply to a hurtful extent prior to the establishment of the fisheries that have been so rapidly depleting them, the answer is, that nature's laws are inflexible and not always readily explained. She permits no infractions of them without revenging herself, though, as in this case, her penalties are not always imposed on the transgressors, but on innocent parties.

That the menhaden supply is being exhausted needs not the saying. Those who were familiar with the coast waters twenty or thirty years ago and are familiar with them now will bear testimony to the fact that during the period referred to it was an extraordinary occurrence if, in sailing through them only for the distance of a mile, vast schools of menhaden were not encountered. A paper before me, furnished by a leading menhaden fishery proprietor, states that at times his boats have steamed 800 miles along the coast without taking a single fish. Such facts speak for themselves. This acknowledged scarcity, whatever may be said to the contrary by the menhaden fishermen, can not rightfully be classed among the fluctuations which mark the movements of such migratory fishes as the mackerel, the herring, and others. The decrease has been gradual, keeping even pace, in inverse ratio, with the increase of the menhaden fisheries, and showing conclusively that if there were ten times as many menhaden in the coast waters twenty years ago as now, as there undoubtedly were, the falling off is justly chargeable to the purse net. The injury already done is not, however, remediless. If the purse net were entirely forbidden by law, or its use placed under judicious restrictions, the damage thus far caused by it might in time be repaired by nature's restorative processes, but as long as the present system is tolerated there is no room for hope of such restoration.

It is a striking coincidence that the decrease of coast fishes began to manifest itself about the time when menhaden fishing first assumed formidable proportions, and it has kept abreast with the work of extermination until, as has already been stated, there has been a growing decrease of edible fishes, which, as far as inside coast waters are concerned, amounted, during the past summer, to practical extermination, and moreover there never were so few menhaden taken.

There is another evil connected with menhaden fishing which merits notice. The formidable purse nets, which are usually 100 feet in depth and 1,800 feet in length, capture not only menhaden, but great quantities of edible fish, which, instead of being separated from those valueless for food and sent to market, after the wants of the crew are supplied, are ground up for oil and fertilizers. This is denied by the menhadenites, but hundreds of witnesses to the truth of the allegation could, if necessary, be furnished—witnesses who would show that bluefish, squeteague, sheepshead, croakers, porgies, striped bass, sea bass, drum, tautog, and nearly every other variety of coast fish are captured by them and utilized as stated.

Replies to these charges have been attempted, and to those not familiar with the facts they will appear plausible. To illustrate, a single affidavit was read before the Congress in which the affiant, who was understood to be a reporter and a passenger on board a menhaden fishing boat, avers that during the entire trip not more food-fish were taken than were needed to supply the table wants of the crew and their only passenger. That such might have been the case is within the range of probabilities. The nets, intentionally or otherwise, may have been cast in waters where edible fish were not plentiful. Therefore, the argument, if an argument it can be called, goes for nothing.

Again, it was alleged that the proprietors of the boats would be grossly unmindful of their interests if, instead of sending the many food-fish said to be taken in their nets to the New York markets, where they would command from 8 to 10 cents a pound, should send them to their factories, where they are worth only a cent or two a pound. That would be poor economy if the food-fishes taken could be disposed of at the prices named; but, for several very conclusive reasons, they could not. It was forgotten to be mentioned that menhaden fishing is mainly carried on during the summer months when edible fish are most plentiful and very perishable; that the average time consumed in a fishing trip is from three to six days, some of them exceeding the longest period; that the menhaden boats rarely, if ever, carry ice in sufficient quantity to preserve, for any length of time, any food-fishes that may be taken; that of all places in which food-fish should be kept, a noisome fishing boat, with its putrefying, unsavory contents, would be the last, and that even if they were not tainted by such surroundings their sale in New York, under such circumstances, is prohibited by law. These plain facts completely abolish that line of defense.

Again, it was argued during the discussion that, with two or three exceptions, the edible fishes of the coast are of the bottom varieties, and, therefore, readily escape from the nets. In answer to this most preposterous argument it is only necessary to state that, generally speaking, the bottom of the sea where menhaden fishing is done is nearly as smooth as a floor. Never, or very rarely, is purse-net fishing attempted in water approximating even to 100 feet in depth. The heavy leads carry the net to the bottom and keep it there. With those leads dragging on the smooth bottom of the sea, the idea that fish, startled by their approach, would attempt to escape beneath them is simply an absurdity. A fish of any kind startled by the approach of the leads seeks refuge by fleeing from instead of toward them, and naturally rises toward the surface. Being intercepted on its course upward by the meshes of the net and by the closing of the deadly purse below, escape is rendered impossible.

Another favorite argument is that the source of menhaden supply is inexhaustible. It is the identical plea that was offered by those who exterminated the buffalo; by those who denuded the forests of Pennsylvania, Michigan, the Southern States, and who are now carrying on their destructive work in the great forests of the Pacific States. The salmon supply only a few years ago was declared inexhaustible, but grim experience has demonstrated the fallacy of such belief. The Columbia River, once the most celebrated salmon stream in the world, has been robbed of its fruitfulness, and the Frazier River supply is rapidly being reduced to a like condition. In order to protect Alaskan rivers from similar depletion, the Government is appealed to for the enactment of restrictive laws.

In this age of greed and of ingenious devices there does not appear to be any natural resources for which there is a market, and the marketing of which will afford a profit, that can properly be considered inexhaustible, and the menhaden supply is certainly not an exception.

In view of such cogent and impregnable facts, is it surprising that the food-fishes of the coast north of Chesapeake Bay are decreasing? In the Delaware Bay, about 8 miles above Cape May, are the "drum-beds," once the finest of fishing-grounds. Squeteague and drum formerly abounded there in their season in such quantities that hand-line fishermen nearly supplied the Cape May market with them. The menhadenites invaded those beds with such effect that fishermen no longer visit them and meet success.

New Jersey made a vigorous effort to abolish the hurtful industry, but its legislative enactment was declared unconstitutional. Another effort to secure its abolition by Congressional action met with failure.

Pound nets.—Another device, injurious in the highest degree to food-fish plentifulness along the seacoast, is the pound net, which of late years has assumed most formidable proportions and which threatens to become still more destructive. Not only have those nets increased immensely in size, but they have multiplied to an extent that certainly calls for legislative interference.

These destroyers of edible fish are placed as early as April and, as they extend a long distance into the sea, intercept tens of thousands of migratory fishes on their way northward. Most of the captures are of spawning fishes, and are mainly sea bass and squeteague, though many other varieties are taken. The nets are continued in position until fall, when the young fish spawned northward of them commence their southward journey. As those young fish generally keep near the shore, they become the victims of the nets, in which they perish by hundreds of thousands—it would not be exaggeration to say millions. That some concentrated and determined effort has not been made to either define the seasons when they can be employed or, what would seem to be more advisable, forbid their use entirely, is surprising. They exceed menhaden fishing in their injurious effects upon edible-fish life. The damage to the edible-fish supply from Sandy Hook to Albemarle Sound has become so marked that a combined effort is about to be made to induce Congressional legislation that will afford the much-needed relief.

SOUTHERN COASTS.

Southern coast waters have, for several reasons, suffered less than Northern. Population is comparatively sparse and consequently the home-market demand for fish is limited; the generally prevailing heat of the weather, the scarcity of ice for packing purposes, and the lack of sufficiently rapid transportation to the great city markets of the North discourage extensive fishing operations. Commercial fishing is therefore an industry restricted to a few months of each year, and necessarily not of great extent nor specially injurious to the natural resources.

PACIFIC COAST.

The marvelous abundance of salmon on the Pacific coast naturally led to the impression that the supply was inexhaustible. This belief, coupled with their great commercial value and the comparative ease with which they were taken, immediately attracted the attention of capitalists. Fisheries were established, canneries on a large scale erected, and the work of destruction began. For a number of years the idea of inexhaustibility was still entertained, but the inroads made upon the immense schools that periodically came from the sea to do their spawning in the fresh waters made it apparent that unless some restrictions were placed upon fishing operations, and close seasons ordered and respected, the time would come when salmon plentifulness would cease. Restrictive laws have been enacted in the States and Territories of the coast, from California northward, but, notwithstanding, each succeeding season clearly demonstrates a decrease, which, with the continued enormous canning and packing operations, can not fail in the course of years to so lessen production as to render the maintenance of these industries upon their present gigantic scale impracticable.

In view of what has been presented, there is no such thing as successful disputation of the fact that from the several causes to which reference has been made, and from the many others that readily suggest themselves, the fish products of American waters have for years been steadily declining. True, there are some that still give evidence of former prolificness, but the number is so small that they are the exceptions that prove the rule. Manifestly, this deplorable state of our fishery interests is due either to the inefficiency or to the non-enforcement of the laws. Nature has had nothing to do with it, except to assert herself when her laws have been infracted. If waters are polluted, the fish she has placed in them either die or seek purer streams. If fish are killed during their spawning seasons, she does not supply others to take their places during that season. These are some of her revenges. Her work is nearly always perfect, and where it fails to be of that character—as far as the maintenance of natural fish-plentifulness is concerned—the failure is the result of man's interference.

It will not be seriously contended by anyone familiar with the subject that the present meagerness of our food-fish supply is due to any legitimate demand for consumption or to any lack of fish-producing waters. The Chinese proper, with a territory not nearly as large as the United States, with a population ten times as dense, with waters that will not compare with ours in extent and variety and which are not in any sense naturally more productive, for centuries before the discovery of America maintained, unimpaired, the fecundity of their rivers, lakes, and seacoasts to an extent that enabled them to make fish their leading article of animal-food diet. That abundance is still maintained. Realizing that the products of their waters must of necessity be their principal source of animal food, instead of—as we have largely done—improvidently "killing the goose that laid the golden eggs," they have carefully nurtured the valuable boon, and with the results stated.

The anomalous features of the case are that no people on the globe are quicker to appreciate or more ready and eager to take advantage of any and every opportunity for increasing individual or national prosperity than are the Americans, and that so many of them close their eyes to the dollar-and-cent value of what could be realized from the products of our waters. Were those products at this time equal to those of sixty years ago, and were they maintained, as they should and readily could be, by more stringent legislation and by general obedience, the result would be an annual addition of millions to our national wealth, and necessarily and naturally be largely promotive of the comfort of the people. Assuming such to be the case, the question for serious consideration is whether, with any means at command, it is possible to restore the former productiveness? Experience has clearly demonstrated that, save in exceptional cases, merely restrictive laws furnish no adequate remedy for existing evils, nor is it probable they ever will. Fear of punishment is not always an efficient agent in the prevention of crime, but it becomes all-powerful when public opinion stands by as its supporter. Until that sentiment has been inculcated up to the standard of a full comprehension of the intrinsic importance—the money value, if you please—of American fishery resources, there will be little room to hope for ultimate success. That point reached, there will be no need for restrictive statutes. The wisdom of guarding food-fishes against injurious molestation will then come to be regarded as an obligation, the faithful discharge of which will be demanded by self-interest as well as by a patriotic regard for the general weal.

The starting-point in this campaign of education is the thorough dissemination of the truth that all fish in the public waters of a State are the property of the State, and that the taking of them, by whatever means the State may prescribe, is a *privilege;*

that the State's guardianship of its public waters is not intended as a curtailment of individual rights, but an undeniable prerogative to be exercised for the promotion of the public good; and that, therefore, to disregard its commands is practically as much a misdemeanor as would be the illicit appropriation of any other State property. While the fish are the actual property of the people, the people have delegated to their legislative representatives the duty of enacting laws for their protection, the same as though they were public property of any other kind. To insist upon compliance with restrictive fish statutes is therefore no more an infringement of popular rights than is the law requiring that public moneys shall be paid over to the State treasurer, to be disbursed by him only in rigid accordance with legislative enactment.

This may seem an extreme view of the case, but, practically and thoughtfully considered, it will bear no such interpretation. When it is thoroughly impressed upon the public mind, the first and most important step in the direction of restored fish-fruitfulness will have been taken.

Not many years ago insectivorous birds were regarded as nuisances, or at best worthless, except for food. Farmers, in many cases, encouraged their extermination. But when their grain fields were devastated, their fruits destroyed, and their incomes lessened by noxious vermin they began to look around for the cause and a remedy. It was very readily demonstrated that the enormous increase of crop enemies was mainly due to the destruction of the birds. Laws for their protection were demanded and enacted. Bird slaughter ceased, farmers laid aside their shotguns, the idle hunters who traversed the country in every direction, invading private property and indiscriminately killing birds of every kind, were driven away, and respect for the laws was insisted upon. To-day the farmers are receiving their reward in the form of increased crops of grain and fruit. It was the *argumentum ad crumenam*—the appeal to the purse—the potent influence of the almighty dollar, that wrought the change, and such would in all probability be the result if people could be persuaded to believe that duty to themselves and to the State demands obedience to the fishery laws, as well as coöperation with the authorities in the efforts that are made to replenish our waters.

Allusion has already been made to the lax manner in which magistrates, constables, and wardens generally discharge their sworn duties in regard to the fishery laws. It is a fact that will not be disputed that, whether from negligence, indisposition, or the dread of being looked upon as informers, in not one case in a hundred are transgressors of those laws called to account, though the authorities whose duty it is to arrest and punish are fully cognizant of the perpetration of the offenses. A reason for this is found in the largely prevalent opinion, already referred to, that fish in public waters are the rightful property of any one who can take them, at whatever season and by whatever means. Officials who honestly discharge their duties are regarded as informers, and it does not need the saying that the rôle of the informer is a very ungracious one, which private citizens are unwilling to play, however strongly they may be inclined to right a public wrong.

But why should this feeling so generally prevail? There is no such hesitancy in respect to other misdemeanors. The sentiment is erroneous and mischievous. It can not be defended either on moral or legal grounds. A magistrate who, having knowledge of the perpetration of a misdemeanor, fails to bring the perpetrator to justice, rightfully subjects himself to impeachment. Why not in cases of misdemeanor such as we are considering? It is to this shirking of duty, this evasion of sworn responsibility, that most of the violations of the fish-protective laws are due. Wherever the authorities have faithfully performed their duties the wrongs have ceased.

Take as an illustration the result of determined official action by the State Fishery Commission of Pennsylvania in regard to fish baskets in the upper waters of the Delaware. When official notice was given that all fish baskets in that river must be removed, there was a general expression of indignation, and the declared determination that any and all attempts to remove or destroy them would be resisted with all the means at command. The lives of wardens who performed their duties were imperiled, the legislature and the courts were appealed to, but the commissioners, backed by law and confident that they were simply fulfilling its behests, continued the crusade until eventually they scored a decided victory. Not a fish basket is to be found in that river to-day. Its productiveness has been restored, as already shown, to the extent of making it the finest shad river on the continent. This gratifying result was accomplished by the simple process of a rigid enforcement of law by the State authorities. The benefits to the inhabitants on both sides of the river are so marked that not only has opposition ceased, but many of those who at first were in open antagonism are to-day the warmest advocates of the healthful reform.

This case is referred to for the purpose of showing what can be accomplished by determined official action, and also to emphasize the opinion already expressed that it only requires a practical illustration of the money value of the fishery interests of the country to secure almost universal and cordial coöperation in behalf of fish-protective reform.

Among other efficient agencies that should and can be enlisted in this campaign of education are fish-protective associations. Already a number have been formed and are in active operation. Some of them have been doing notably good work in behalf of fish-protection, having greatly aided the authorities in the creation of a sound, healthy public sentiment. Most of them have largely assisted in the judicious distribution of young fish in waters in their vicinity, and thereafter in protecting them. There can not be too many such associations. There is room for thousands more, and thousands more would doubtless be organized if the young men were fully informed as to their specific object and the great amount of good that would certainly follow energetic action. The effect upon popular sentiment could hardly be overestimated; therefore, all possible encouragement should be given to efforts in behalf of the formation of such associations.

Another powerful auxiliary is the newspaper press. It is not risking much to assert that there is not a newspaper of any repute in the country that will not willingly give the full weight of its influence in behalf of this great work. Such powerful support will not be grudgingly given, nor in stinted quantities. Editors will need no urging. All that will be necessary will be the furnishing of the facts desired to be placed before the people in order to insure their publication, with comments that will add immensely to their cogency. It would be a libel upon the newspaper fraternity of the country to intimate, even, any other course on their part. There is nothing partisan in this proposed campaign. Democrat and Republican, Populist and Prohibitionist, are alike interested in it, and when convinced of its immense importance to the country there will be a joining of hands and concert of action that will be the sure harbingers of success.

Let me, by way of recapitulation, enumerate some of the essentials to success:

(1) The inculcation, to the extent of a full comprehension, of the truth that the fish in the public waters of a State are the property of that State, and the taking of them, by any means, a privilege.

(2) That the guardianship of such waters and their finny inhabitants is the sworn duty of the people's representatives, just as is the guardianship of any other kind of public property.

(3) That the laws enacted in order to make that guardianship effective are binding upon and demand implicit obedience from all.

(4) That it is the sworn duty of sheriffs, magistrates, constables, and fish wardens, as far as they have cognizance and jurisdiction, to arrest or cause to be arrested and tried, and without fear or favor, any and all offenders against the restrictive statutes.

(5) That it is a patriotic obligation resting upon all citizens to aid the authorities in their endeavors to restore the original fecundity of American waters, for the reason that such restoration would benefit the country annually to the extent of millions of dollars.

(6) That it is the duty of the people's representatives in Congress to enact laws that will place the menhaden and other coast fisheries under such restrictions as will prevent the edible fishes from being so largely and wastefully diminished in numbers as they have been for years past, and still are.

(7) That artificial propagation, judicious distribution, and the thereafter protection of edible fishes should be prosecuted to the fullest needed extent by every State and Territory.

(8) That fish-protective associations, being potent helpers in the work of restoring edible-fish fruitfulness to our waters, should be warmly encouraged in every State, and the powerful aid of the newspaper press of the entire country evoked in its behalf.

If, after having employed these several means—together with others that will naturally suggest themselves—for the repopulating American waters that have been wholly or in part depopulated, there is not decided increase in their fish products, further efforts may be regarded as a waste of time and money. But such a result should not be deemed probable, nor should even the possibility of it be for a moment entertained.

5.—THE SEA AND COAST FISHERIES.

BY DANIEL T. CHURCH.

Personally I am a commercial fisherman and have been connected with the fisheries from my youth to the present time. It is my belief that fish that live and spawn in tide water are inexhaustible and that no mode of capture yet invented in the form of seines and traps is able to make any appreciable difference in the supply. Floods and droughts of all tide-water fish are the rule and the fluctuations would be just as marked if man never took a fish from the water.

Thirty years ago it was claimed in England, as it is in the United States to-day, that improved methods of taking fish with nets, seines, and other contrivances were diminishing the supply of fish, and the Queen appointed James Caird, Thomas Henry Huxley, and George Shaw Lefevre to inquire into the condition of the sea fisheries of the United Kingdom of Great Britain and Ireland. Their conclusion, after three years' exhaustive inquiry, was expressed as follows:

> We find the laws relating to sea fisheries to be complicated, confused, and unsatisfactory; many restrictions, even of late date, are never enforced; many would be extremely injurious to the interests of the fishermen and of the community if they were enforced, and, with respect to these and others, the highest legal authorities are unable to decide where and in what precise sense they are operative.
>
> We advise that all acts of Parliament which profess to regulate or restrict the modes of fishing pursued in the open sea be repealed, and that unrestricted freedom of fishing be permitted hereafter.
>
> For the present we advise that all acts of Parliament which profess to regulate or restrict the modes of fishing pursued inshore be repealed, with the exceptions, purely on grounds of police, of the local act regulating pilchard fishing at St. Ives, and, for that part of Loch Fyne which lies above Otter Spit, of the act prohibiting trawling for herring in Scotland.
>
> It may be instructive to consider the action of the Dutch government, the sea fisheries having been for three centuries a matter of care and prominent interest in Holland. Their present position is referred to in the following words of the King's speech at the opening of the legislative session of 1865–66: "The produce of the fisheries, both in sea and river, is most satisfactory."

Referring to the Dutch fisheries the English commissioners state:

> Up to 1857 the Dutch fisheries were burdened with many restrictions intended for their protection and encouragement. The period within which herrings could be fished was limited. The places of fishing, the times, the nets, and the tackle were all under regulations. But the fishery languished and declined, and it was determined by the legislature to try the effect of another system. A law was passed in 1857 abolishing all restrictions, regulations, and enactments as to close time, trawls, nets, and lines. Every one was left free to fish the sea in any mode and at any time he deemed most advantageous, while a fishery commission was established to collect the statistics of the various fisheries and report annually to the legislature upon all matters affecting the interests of the fisheries.
>
> The result has been a steady and continuous improvement. The last report of the commission shows greater anxiety to find new markets in foreign countries for the fish than about the prospects of an abundant catch. The commissioners conceive that the future prosperity of the Dutch fisheries will depend on a profitable outlet for the fish being found by a freer intercourse with neighboring countries. A return is given of the number of vessels employed in the herring fishery at Scheveningen and their annual catch, which rises from 24,969,000 in 1858 to 33,535,000 in 1864. The export of cured herring from all parts of the country had risen from 30,919,271 "stuks" in 1858 to 42,698,000 in 1864.

In 1870 it was claimed that fish on the New England coast were being depleted by the use of traps and seines, and a determined effort was made by the legislatures of Massachusetts and Rhode Island to pass laws to suppress them, but it failed, and in spite of their use the floods and droughts of fish have happened with their usual regularity.

During the year 1890 scup were as plenty as ever known since their appearance in 1800, and the following figures are instructive, showing conclusively that for the last ten years they have more than held their own with unrestricted trap fishing:

The number of barrels shipped from Newport were:

Year.	Barrels.	Year.	Barrels.
1882	8,389	1888	13,337
1883	8,865	1889	17,597
1884	16,062	1890	7,696
1885	15,263	1891	17,562
1886	14,586	1892	25,253
1887	14,460		

In 1892 tautog were exceptionally plenty, and in 1893 squeteague were plentier than ever before known.

Sam B. Miller, who has had over fifty years' experience in Fulton fish market, has sent me the following letter, which is instructive in this connection:

> D. T. CHURCH:
>
> DEAR SIR: Your letter at hand asking for information about blackfish. Well, I will say that they are very plenty and very cheap. I have no recollection of seeing them more plentiful in the last fifty years and at the end of the season, for shipping them in barrels. The smacks began to arrive with live ones, until at one time it was estimated there were alive in the dock more than 100,000 pounds. But they are out at a much less price than any year for the last ten years. Bluefish and weakfish have been through the season very plenty. I never knew weakfish as plenty and as cheap in my time; 1 cent per pound was considered a good price for many days, and many tons were sold for less.
>
> S. B. MILLER.

From 1870 to 1893 similar floods and droughts have happened to every fish known to our coast fisheries.

The menhaden fishery, one of the most important in the country, is being ruined by the stringent laws enforced against it by several of the seaboard States. Millions of barrels of menhaden have been in Buzzards Bay this season with fishermen and factories idle, because Massachusetts will not allow them to be taken with nets in that bay, resulting in disaster to invested capital and labor and fishermen depending on that fishery for their daily bread; also in a short crop of oil, causing our oil merchants to send to Japan for fish oil of an inferior quality at a higher price. The Maine menhaden fishermen had a similar experience in Maine in 1891, causing a heavy loss of money, which badly crippled those engaged in that fishery in that State. Last year the State of Delaware arrested and made trouble for the menhaden fishermen in Delaware Bay and so did the State of New York in the head of Long Island Sound.

In the light of the above facts I would suggest that this Fishery Congress recommend to the Congress of the United States the appointment of the head of the U. S. Fish Commission, Eugene G. Blackford, and Tarleton H. Bean, to inquire into the condition of the sea and shore fisheries of the United States, with powers similar to those given to the English commission, and have them report their conclusions and recommendations the same as the English commission did at the end of theirs.

6.—OUR OCEAN FISHES AND THE EFFECT OF LEGISLATION UPON THE FISHERIES.

BY J. M. K. SOUTHWICK,
Fish Commissioner, Newport, Rhode Island.

No question can arise concerning our fisheries of more importance than that relating to our ocean fisheries. Of ocean fishes that particularly interest us at this time are those that periodically visit our coast and remain in our waters during the warm weather. The taking of these fish has become an important industry, its value is far-reaching; besides those directly employed, it ramifies into almost all departments of industry and trade. It stimulates the business of the mechanic, the manufacturer, the merchant, and has become an important factor to the farmer, furnishing an essential and valuable fertilizer.

Statistics give but a partial idea of the relative value of this compared to other industries, for of this branch for every dollar represented as the product there are 100 cents added to the country's wealth; besides this there is a great unknown quantity not accounted for, taken by everybody who chooses that can get at the water.

Besides the industrial side of this question, there is one not to be ignored or overlooked. I refer to the sport or recreation derived from fishing. It amuses the child, it affords relaxation to the professional man, the merchant, the mechanic; everybody who will, may derive pleasure from it, and we hold that this should be fostered and encouraged as an essential to the health, comfort, and pleasure of the people.

The fishery is the spontaneous gift of nature to man and is without stint, as in the beginning "the waters brought forth abundantly."

In the utilization of this bounty of nature it is important that we do it wisely. It deserves and should have the most thorough investigation and the wisest counsel of the students of natural history and political economy.

The habits of the different species, their varying numbers, their absence for long periods, their sudden reappearance, their appearance in waters where never before seen, are interesting phenomena, the effects of natural laws but little understood and which baffle the most astute student. But of one thing we can be sure, that the fluctuations in numbers have ever been and ever will be a law of their existence. Nor is this strange. It would indeed be strange were it not so. Their fluctuations have been noticed all along through their history and were as marked in the past as in the present, probably more so.

In considering this subject of fluctuations it will be well to note some of them more definitely. The scup, the most numerous of all our edible fish at present, were unknown in our waters one hundred years ago. Since that time the bluefish have been twice absent and were very rare and small at the beginning of this century; now they are large and abundant. The past season surpasses all others in the number of squeteague.

Butterfish have of late become very plentiful; they are to be seen in immense schools off the coast and they were but little known in the past. The bullseye, that were very plentiful within our memory and totally disappeared for many years, have again returned. The Spanish mackerel, that put in their appearance a few years ago, were before unknown to us and now are getting less and may again leave us altogether.

The species most diminished in our waters are the anadromous fishes that seek the fresh upper waters of our streams. Some of these have been so long absent, or their number so reduced, that we hardly realize they were once abundant here. Among these are the salmon, shad, herring, and bass.

Since these very radical changes are known to have taken place before the use of improved methods, and inasmuch as the quantity taken by them is exceedingly small compared to the known destructive agencies, the effect could not be worth considering. Yet this has been made to loom up to the greatest importance, and is made to vitally affect and involve our whole industrial fishery.

The question whether sea fishes may or may not be affected in numbers by overfishing has been as definitely settled as it can be, by the most thorough investigations of the past, in this and foreign countries, but the conclusions arrived at fail to be recognized by the local authorities, and many of the States have enacted laws at variance with them. To justify such repressive laws, it should be made to appear that continued free fishing was working an injury to somebody or something, or destructive to the fish, and that the injury affected interests greater than itself. As it is presumed that no injury will be suggested other than the alleged reduction of the fish, we will consider that only.

That the fish are being reduced in numbers and that the reduction is caused by overfishing are the charges made against net fishing. The reply is, that fish are not being reduced; that if they were, it must be from natural causes. Statistics show that after fifty-seven years continual use of the purse net in fishing for menhaden the largest catch was made in 1884; and after fifty years continual fishing for scup the Rhode Island shipments of this fish were swelled from 12,514 barrels in 1882 to 28,955 barrels in 1892.* The statistics of catches in European waters go to confirm our own, and show rather an increase than diminution. To this we have the added declaration of the most able investigators, both there and here.

The late Prof. Baird thought in 1871 that it was necessary, in order to preserve the scup, to restrict in some degree the catches of that fish by traps, but in 1877 he stated before the Halifax Commission:

> Very much to my disgust, I must admit that the next year, even with all the abundance of these engines, the young scup came in quantities so great as to exceed anything the oldest fisherman remembered. Since then scup have been very much more abundant than when I wrote my book and report.

To this the reply comes that statistics are not a true indication of the fisheries; that increased facilities have made it possible to catch even in increased numbers. We reply that if this is good logic for a year or two, how is it when applied to the business continued for a long series of years, as with the herring fishery of the North Sea, the scup fishery of Rhode Island, and the menhaden fishery of our Atlantic coast? How long can this increase of fish manifest itself before the arrival of the time predicted when they will be totally exterminated?

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* Most of these fish were scup, and the increase probably wholly scup.

Then we are treated to the following argument, from a memorial sent from the towns bordering on Buzzards Bay:

> The natural result of seining, even in the open sea, is extinction. The same senseless rapacity of man which has exterminated our buffalo, which has destroyed the whale fishery, which is aiming to ruin the fur-seal fishery of Alaska, and which will, if unchecked by legislation, kill all Massachusetts game in a few years, has found even the apparently inexhaustible fertility of the ocean unable to resist the assaults of netting.

The fallacy of this reasoning is too apparent. It is possible to exterminate one form of life and not equally so another.

The mammals generate by a slow process of one at a time, while the fish propagate by thousands and millions; their spawn is estimated from 10,000 to 9,000,000. It may be that these mammals may be brought to the verge of extermination, but it does not follow that the rats and mice, the flies, or the mosquitoes may. We wish they could, and now were, but we fear they never will be. And we are quite as sure the fish of the sea will never be exterminated until the Ruler of the Universe puts his hand upon them through some one of the natural agencies at his command.

The confidence manifested in the ability of the fishermen to exterminate the fish would justify a contract with them for the extermination of the pests that annoy us. Since "by the application of means to an end by men, that end is sure to come as a sequence," according to the reasoning of these men, the children of to-day may congratulate themselves that when they are old enough to take their noon nap they will hear no buzzing of flies or mosquitoes nor be bitten or stung by these pests of our lives. The poor horses will also escape these torments—think of it ye members of a society with a long name!

In view of the evidence gathered by past investigation and the estimates of the destruction of fish by different agencies, the insects present much better illustration of the effect of fishing by man upon the fish than do the mammals so often referred to. The number of fish in the sea is as far beyond our estimation as the insects and can be no more influenced by legislative acts. Most, if not all of them, have at times been absent within the last or present century before the use of new appliances that are considered destructive; hence the changes were from causes independent of the acts of man, and natural causes; besides we have the best of authority for saying that the powers of man are inadequate.

In the consideration of a subject it becomes essential to know the experience of the past, what has already been learned concerning it. It would be the extreme of conceited egotism to ignore the past and attempt to evolve from our own narrow experience alone conclusions upon a subject like that of our fisheries. We therefore look to the record of past investigations; we find there has been much patient labor and careful thought bestowed upon this subject. We should pause long and look carefully before accepting conclusions adverse to those arrived at after such thorough research and investigation.

We can not, therefore, treat this subject fairly without quoting freely from the reports of the past, even though they are familiar to all. The English commissioners, James Caird, Thomas Henry Huxley, and George Shaw Lefevre, as able and competent men as could be found in any country, gave three years to this subject, asked and received answers to 61,831 questions, and visited all the important fishing ports. From their report in 1866 we find the following:

Report of fish that were forwarded over four British roads.

	Tons.
1856	11,714
1857	15,156
1858	21,615
1859	27,660
1860	27,668
1861	33,337
1862	36,869
1863	37,833
1864	40,337

Returns of twelve roads for three years.

1862	99,724
1863	108,721
1864	122,381

The figures clearly show an increase continued for these years named, without a break, every succeeding year showing an increase over the preceding one. Of the Scottish herring we have as follows:

	Barrels.
For 5 years ending 1844	3,039,000
1849	3,110,000
1854	2,983,000
1859	3,026,000
1864	3,372,000

On the eastern coast of Scotland and England herring just ready to spawn have been captured in great and steadily increasing quantities every year for centuries, and yet the number of herrings is as great if not greater than ever.

The supply of any kind of fish should be permanently diminished by this great and constant destruction of the breeding fish or the young fry; and yet nothing is more certain than that in many cases this apparent necessity does not exist. In fact, the argument to which we refer owes its apparent force to the fact that it overlooks one of the most important conditions of the question. It is assumed that any destruction of fry effected by man bears a large ratio to the destruction resulting from other causes, an assumption which in several cases is certainly and is most probably altogether erroneous.

We agree with the Royal Commissioners of 1862 in regarding the act enforcing close time on the west coast of Scotland as incapable of any justification, and as having been cruelly injurious to the interest of a large number of fishermen (LXXX).

Up to 1857 the Dutch fisheries were burdened with many restrictions intended for their protection and encouragement. The period within which herring could be fished was limited. The places of fishing, the times, the nets, and the tackle were all under regulations. But the fishery languished and declined, and it was determined by the legislature to try the effect of another system. A law was passed in 1857 abolishing all restrictions, regulations, and enactments as to close time, trawls, nets, and lines; every one was left free to fish the sea in any mode and at any time he deemed most advantageous, while a fishery commission was established to collect the statistics of the various fisheries and report annually. The result has been a steady and continuous improvement. The last report of the commission shows greater anxiety to find new markets in foreign countries for the fish than about the prospects of an abundant catch. A return is given of the number of vessels employed in the herring fishery at Scheveningen and their annual catch which rises from 24,969,000 in 1858 to 33,535,000 in 1864. The export of cured herring from all parts of the country had risen from 30,919,271 stuks in 1858 to 42,698,000 in 1864.

CONCLUSIONS.

> The total supply of fish obtained upon the coasts of the United Kingdom has not diminished of late years, but has increased, and it admits of further augmentation to an extent the limits of which are not indicated by any evidence we have been able to obtain (CVI).

RECOMMENDATIONS.

> In consonance with the conclusions enumerated above we humbly submit the following recommendations to Your Majesty:
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> We advise that all acts of Parliament which profess to regulate or restrict the modes of fishing pursued in the open sea be repealed and that unrestricted freedom of fishing be permitted hereafter.

The following is from a lecture by H. W. Duff, member of Parliament:

> Is there any ground for the statement we sometimes hear that the sea is being overfished? I believe investigation will prove that there is no cause for alarm. I believe it can be proved that our constant fishing has had no appreciable effect in diminishing the number of fish in the sea.

Did time and space permit we would be glad to quote more from the late Prof. Baird of the destruction of fish by bluefish and of the increase of scup, notwithstanding the great increase of engines of destruction. Also from our present Commissioner showing that there has been no diminution of the menhaden.

Of ocean fishes peculiar to our locality none have a more important place than the menhaden. Although not classed among our edible fish, they contribute the means to supply many tables with edible fish and other edibles as well. Their great commercial value is in the oil taken from them and the fertilizing quality of the residue after extracting the oil. This product has, by the aid of improved methods, built up a large and important industry where none before existed; and it appears that none would take its place were it destroyed.

The menhaden is one of the wandering ocean fishes that visit all parts of our Atlantic coast and often show great abundance at one point and scarcity at another, massing at certain points in a way that is phenomenal; but we have not learned that at any time they were entirely absent from our coast during a season. That such may have occurred is very probable, as they were never considered a very desirable edible fish, and very few fish sufficed for all the wants of early times, when no means existed of preserving and the slow methods of transporting practically narrowed the market to a very restricted limit near the coast.

Their use for manure—and later, oil and manure—led to the development of the purse net, first from boats, then small sloops and schooners, and finally steamers, and in the last there has been a great advance over the first. The year 1890 was the culminating point in the history of this fishery in Rhode Island. Later years unfavorable fluctuations of numbers in our waters or restrictive measures by some of the States caused a small catch that if continued would soon destroy permanently the business. It becomes a very serious question to those who have large investments in this industry whether their property can be utilized again in this business, or must be sacrificed.

This particular fishery differs from all others, inasmuch as the fish differ in their habits and the business can not well be confined to the narrow limits of one State. No State could profitably conduct the business wholly within its limits, owing to the capricious movements of the fish.

As no diminution occurred before, and no increase appears since the passage of the restrictive laws, we fail to see any benefit to those States from the adoption of such measures, but a loss to the industries of these States to the measure of their respective interest in the business.

There seems to be a popular idea that legislation is a remedy for all the evils relating to the fisheries, when in truth it is as impotent to effect the purpose desired as an edict of Pharaoh against the pests of Egypt would have been. Repression or restriction is asked for, until we have been led to think that fishing was no longer looked upon as a legitimate or proper occupation. Nor have they stopped at legislative restriction of the fisheries in public waters, but have restricted the sale of the product of one's own toil upon his own private domain.

As has been suggested to the Commissioners, if they go too far they will find that the people will have no further use for such masters. No doubt something like this led the governor of New York in a recent message to say of commissioners of fisheries:

> Their efforts should be directed mainly, however, to increasing the supply of food-fish. Merely as conservators of sportsmen's interests their official existence and powers would scarcely be justified by the tax-paying public. The scope of their responsibility and the measure of their opportunity are much wider than is prescribed by any such narrow field.

In the fresh-water ponds and streams the fish are very much restricted in their movements, and it is doubtless possible to destroy the fishing in them by reckless use of means that would be ineffective in the ocean. It appears that very many of those interested in fishes got their experience in the fresh-water fishery, and there learned the necessity of repressing reckless methods that were working the rapid destruction in the streams and ponds of fish in a manner both cruel and wanton. It is not strange that with such early experience they are often led to apply the same measures to our free ocean fisheries and sometimes overlook the interests and magnify the evils of the industrial sea fisheries. To have any just appreciation of this subject one should be in touch with the fisheries and those engaged in them.

The investigator, not too much biased, soon learns to distrust the knowledge he began with and felt so confident of; and after years of patient research and earnest study he is not a little chagrined when he sums up his knowledge to find how little he knows or rather how much he does not know. We deem it an evidence of progress in the investigator when he has learned how little he knows. We have met those who knew it all to begin with, but never found such to advance a step. Such men will not stop to reason or abide the demonstration of facts; they are content to condemn all who differ, and, like the old lady, think it strange all such are always in the wrong.

We are aware of the place they will assign us. We are also aware that we may be taking the least popular side of the question, but it is a satisfaction to us that when we undertook the duties of fish commissioner we were pledged to no particular measures or men, and we trust we shall always be found giving our best services to the duties devolving upon us, but never forgetting that we are also citizens and are ready to become private citizens as soon as the public good can be better served. But while holding the position we will endeavor at least to be candid and impartial in the discussion of all questions, suppressing no facts nor exaggerating any statement to advance one side or the other of a controversy.

The question whether sea or ocean fish may or may not be affected by overfishing has been settled as definitely as it possibly can be by the ablest and most thorough investigation. And to sustain the position assumed against menhaden fishing it becomes necessary to change the classification of these fish from ocean fish to anadromous fish. We supposed all had too much confidence in the thoroughness of the late Prof. Baird to believe his conclusions were without warrant, and before accepting conclusions at variance with his it is but fair to give some new data.

It is certain that the great mass of menhaden never penetrate far beyond tide water; that some few sometimes get separated from the main body and cast their spawn when ripe wherever they happen to be, seems possible, and under favorable conditions a fair show of fish may thus be produced. This would prove no rule, but an exception. It seems self-evident that if this, the most numerous of all our fishes, came in masses into any of our waters to cast their spawn, they would be observed. While we would avoid being dogmatic about anything concerning fishes not fully demonstrated, we think it safe to say (in the light of all present knowledge) that they are ocean spawners and ocean fish, as much as any other fish that visit our waters, and we should feel it idle to contest the point, were it not that two great States have enacted laws based upon the opposite theory.

Would it not be well before we attempt too much control of the fisheries of the ocean to learn more of them—at least, to know that we are not making matters worse, and until then leave it to the allwise Ruler of the Universe, who has been their only ruler for six thousand years?

THE EFFECT OF LEGISLATION UPON THE SEA FISHERIES.

There has been much of it both in this and in foreign countries. Either the laws have operated to protect the fisheries and benefit the people or to harass the fishermen and crush out the industry. Which? If any good or salutary effect has been produced by it, it ought to be manifest by this time. We challenge its friends to point to one instance where restrictive laws over the sea fisheries have benefited the fisheries or caused the increase of numbers of any one fish. If it can not be shown to do the one, it may fairly be charged with doing the other.

The effect has been shown to cripple and injure the Dutch and the English fishermen, and to work "cruel hardship upon their fishermen." Does it do less here in America? Will their fish and fisheries thrive and flourish only under freedom, and ours under all manner of restrictive laws? Is their experience of no value? Have we learned more than they? Are only we wise? "Will wisdom die with us?" Shall America adopt the oppressive measures that they cast off, and under which their fisheries languished?

The wisdom or statesmanship that leads to the suppression of an industry giving employment to a large class of our people may well be questioned. But when it occurs at a time when other industries are depressed it must add to the class of idlers whose numbers are already too large and be fraught with evils that endanger the morals and menace the peace of society.

7.—THE PAST, PRESENT, AND FUTURE OF TROUT-CULTURE.

BY W. L. GILBERT.

Probably no business ever entered into by the people had such flattering prospects of success and was, in its nature, so fascinating as the artificial cultivation of trout, and at the same time was so discouraging in the results attained. It was very easy to procure and impregnate the eggs and hatch the trout, but to raise them to market size was quite another thing, and those who were early in the business well remember the fine lots of healthy young trout fry hatched during the winter and placed in the rearing ponds in early spring, only to see them die and fade away as the dew before a July sun. It was, I think, the most discouraging business ever undertaken by man. Many gave it up disgusted, and many articles have appeared in public print proclaiming that trout could never be raised for the market economically. We are now prepared to show that trout can be raised in almost unlimited quantities. Massachusetts alone has facilities for raising millions of pounds annually, and this is also true of nearly every State north of Mason and Dixon's line. When we can take a spring-fed brook of, say, 100,000 gallons per hour capacity, and which in a state of nature did not produce 50 pounds of trout annually, and by applying scientific methods make it produce 20,000 pounds annually, some idea may be formed of the grand possibilities of trout-culture. Incredible as this may seem, it is none the less a fact.

It will thus be seen that the artificial cultivation of trout is no longer a matter of doubt. The business has now passed through the experimental stages, and all that stands in the way of its becoming one of the great industries of the people is the present arbitrary, unjust, and, I believe, unconstitutional laws of the several States which deny the trout-grower the right to sell his product in accordance with the demands of the market. If the expansion of trout-culture, so earnestly wished and worked for, is ever to be realized in America this stumbling-block of overprotection must first be removed. Remove this, legalize the business, grant to the trout-grower the same rights and privileges that are freely accorded to all other citizens and tax-payers who are engaged in an honorable and legitimate industry, namely, the right to sell their product when it is most needed, and trout farms will spring up all over the country, and this delicious fish will be raised in immense quantities and as cheaply as poultry, thus giving employment to individuals, profitable investment for capital, and a delicious food product during the winter months, when most needed.

When we take into consideration the vast possibilities of trout-culture, and also the fact that the supply of fish from natural sources is fast being exhausted, it seems a suicidal policy for any state or nation to pass and still persist in maintaining laws which shall in any way interfere with the development and expansion of fish-culture.

Allow me to say in closing that it seems to me highly appropriate that this Congress, which represents with such intelligence and ability all fishing interests of every kind of all the nations of the earth, should take the initiative in a matter of such vital importance to trout-culture; and I predict that if its efforts should be crowned with success it will receive the thanks of every friend of trout-culture in the land.

8.—THE RELATION OF SCIENTIFIC RESEARCH TO ECONOMIC PROBLEMS.

BY GEORGE BROWN GOODE,
Assistant Secretary of the Smithsonian Institution.

Address as Chairman of the scientific section of the World's Fisheries Congress, Columbian Exposition, Chicago, October 17, 1893.

It would seem quite unnecessary at this period in the history of civilization to plead for the right of science to participate in the discussion of economic problems, or of any problems whatsoever which may concern mankind.

"Natural science is no longer content with the contemplative attitude which sufficed for Newton and Laplace. Science is now concerned with all the personal acts of our existence; she intervenes in all measures of public interest; industry owes to her its immense prosperity; agriculture is regenerated under her fostering care; commerce is forced to take her discoveries into account; the art of war has been transformed by her; politics is bound to admit her into its councils for the government of states. How could it be otherwise? Have not mechanics, physics, chemistry, the natural sciences, become intelligent and necessary agents for the creation of wealth by labor? If comfort is more universal, the life of man more prolonged, wealth better distributed, houses more commodious, furniture and clothing cheaper, the soldier better armed, the finances of the state more prosperous, is it not to the sciences that all this progress is due? Whether we wish it or not, we must needs accept Science as a companion, to possess her or to be possessed by her. If you are ignorant, you are her slave; if you are skilled, she obeys you. The future belongs to Science; unhappy are they who shut their eyes to this truth."*

We celebrate this year in Chicago the discovery of America, the end of the dark ages, the birth of individual freedom and of popular government. We celebrate at the same time, it seems possible, the beginning of a new epoch. The mediæval renaissance was limited to Europe; ours will embrace all the nations of the earth. It may be that this should be considered the outgrowth and fulfillment of that which marked the end of the middle ages; but whether we are at the beginning of a new movement or the culmination of an old one, the last forty years have undoubtedly witnessed greater changes in the spirit of men's thoughts than the four centuries which had gone before.

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* Address of M. Dumas, President of the French Association for the Advancement of Science, at the Fifth Annual Meeting, Clermont-Terrand, August 18, 1876.

The earlier renaissance gave to man the right and liberty to think and act as he in his own judgment saw fit. The renaissance of to-day is leading men to think, not only with personal freedom, but accurately and rightly. Far be it from me to assert that mankind in general are very much nearer to accurate and just standards of judgment than they were four hundred years ago; but the spirit of to-day favors the untrammeled and searching investigation of every question in which man is concerned, the critical comparison of the results of such investigation, and frank intolerance of all illogical or unsound theory and application. This is the spirit of science, the spirit of unprejudiced search after truth, and this is emphatically the spirit of the thinking men of to-day in every part of the world.

Whatever may be the ultimate and full outcome of the forces now at work, it is certain that a great industrial and economic revolution has already taken place, and that science is fully recognized as the power by which, in future, the material interests of mankind are to be regulated.

Speaking thus of science, it is not my purpose to include solely that body of professional men who are customarily classified as "scientific men." I use the term in a broader sense, with the meaning that every man who applies accurate observation and deduction to the solution of any problem whatsoever is in some degree a man of science.

Science is knowledge, nothing less nor more. It is needless to add the word *exact*, for knowledge which is not exact is not knowledge at all.*

Science aims to be not only exact, but complete, and, when true to itself, never attempts to conceal its own shortcomings.

Scientific methods of work are simply methods based upon accurate knowledge of what is already known and due allowance for the uncertainties of the unknown.

Science implies not only complete and exact knowledge, but accurate methods of thinking based upon it. When there are differences of opinion in regard to the solution of any scientific problem, there is but one way to arrive at the truth: There must be further investigation. This will confirm or set aside the results of previous researches and perhaps bring out new truths as well. Argument is often unscientific. Darwin used little argument in his "Origin of Species"—that wonderful book which has had more influence on the thoughts of the men of this century than any other not religious or ethical. He marshaled his facts in classified ranks, and after a modest suggestion of his own as to what their meaning might be, he left his readers to make deductions for themselves.

Fifty years ago the domain of science was much more restricted than now. Her votaries were few, and there were among them but a limited number of scholars of high ability. Men of energy and ambition found slight inducement to enter this field of activity, for the rewards were manifestly not great, and even opportunities for study and the discovery of truth—the greatest of possible rewards—were almost entirely wanting. Economic science was in a crude state, and the circle of the sciences was limited. The empirical methods of long ago were still very influential in almost every department of study.

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* "Knowledge," says Cardinal Newman, "is called by the name of Science or Philosophy, when it is acted upon, informed, or impregnated by reason."

To-day all has changed. Science has ceased to be a pursuit and has become a mode of thought, and is an essential factor of learning in every department thereof, liberal or useful. The philologist, the historian, the social and political economist, and the jurist employ scientific methods. Every intelligent man uses them in the consideration of every serious question.

There are differences of degree in the manner in which individual men are scientific. Scientific research involves four processes: (1) observation; (2) the record of the results of observation; (3) the classification and assimilation of these results; (4) their interpretation, both for immediate use and as a guide for subsequent inquiry.

While facts may be observed effectively by any intelligent man, and may be recorded by any person who has been educated to use instruments of precision and to write, it is only the scholar who can classify these records, assimilate them, and incorporate them with the stores of knowledge already in existence, while the man who makes successful interpretations must be to some extent a philosopher.

I had intended to illustrate my meaning here by citing some instances of the relative importance of these various processes in the consideration of an economic problem, but I am disposed to believe that an illustration of a different character will serve my purpose better, and I quote from Bishop Latimer, in the last sermon which he preached before Edward VI, of England, in 1530:

> Here, now [said he], I remember an argument of Master More's, which he bringeth in a book, that he made against Bilney; and here, by the way, I will tell you a merry toy. Master More was once sent into Kent to try (if it might be) what was the cause of the Goodwin sands and the shelf that stopped up Sandwich-haven. Thither cometh Master More, and calleth all the country before him, such as were thought men of experience, and men that could of likelihood best certify him of the matter concerning the stopping of Sandwich-haven. Among others came in one before him, an old man with a white head, and one that was thought to be little less than an hundred years old. When Master More saw this aged man he thought it expedient to hear him say his mind in this matter (for, being so old a man, it was likely he knew most of any man in that presence and company); so Master More called this old-aged man unto him, and said: "Father," said he, "tell me if ye can, what is the cause of the great arising of the sands and shelves here about this haven, the which stop it up, and no ships can arrive here? Ye are the eldest man that I can espy in this company, so that if any man can tell any cause of it, ye of likelihood can say most to it, or, at leastwise, more than any man here assembled." "Yea, forsooth, good master quoth this old man, for I am well-nigh an hundred years old, and no man here in this company any thing near unto mine age." "Well, then," quod Master More, "how say you to this matter? What think you to be the cause of these shelves and sands that stop up Sandwich-haven?" "Forsooth, sir," quoth he, "I am an old man. I think Tenterden steeple is the cause of Goodwin sands: for I am old man quoth he, and I may remember the building of Tenterden steeple, and I may remember when there was no steeple at all there. And before that Tenterden steeple was in building there was no manner of speaking of any flats or sands that stopt up the haven; and, therefore. I think that Tenterden steeple is the cause of the destroying and decay of Sandwich-haven."

Here is an example of thought which is faulty in all its processes—imperfect observation, substitution of memory for written records, absolute inability to classify and assimilate, and deductions absolutely without relation to the foundations on which they are supposed to rest. Had he lived at the present day this rustic philosopher would have wrongly described himself as a *practical man.* He would have been in error, for nothing is less practical than ignorance and poor thinking.

The most serious obstacle to economic progress is the attitude of a certain class of men who, seemingly proud of their own limitations in knowledge and training, boast that they are the *practical* men, and therefore best qualified to deal with all material matters. These men are unworthy of the name which they assume.. They are our heritage of years gone by. In the familiar language of the day they are "back numbers."

The man truly practical is he who knows the boundaries of his own knowledge.

With exact and full knowledge, the treatment of economic questions is simple and easy. The American farmer understands how to raise a full crop of corn or tobacco on rich soil, and if his soil needs strengthening, or his foes and rivals in the animal or vegetable kingdom become too strong, he may summon experts in agricultural science who know just how to relieve him from his foes.

When, on the other hand, knowledge in regard to an economic problem is inexact or incomplete, it is in the province of scientific research to determine exactly what is to be done. All the facts, or supposed facts, must be brought together, weighed, analyzed, and classified. Prejudices, traditions, and false opinions must be eliminated, and a true estimate must be made of the facts which remain. A map must be drawn showing how much of the field of knowledge has been traversed and how much is unknown—a map corresponding to that of North America at the beginning of the century, which our exploring parties had when they set forth to discover the sources of the Mississippi and the western limits of the continent. Then, aided by all necessary appliances for exact investigation and guided by the most logical methods of deductive reasoning, a series of researches must be begun which shall continue until a full understanding has been reached, not only of the subject itself, but of its relation to the kindred problems which touch it upon every side.

This is the province of modern science in the discussion of economic questions.

The arts and industries of man are separated naturally into two classes. The primary or exploitative industries are those by which the fruits and resources of the earth are gathered. The secondary, the elaborative or manufacturing industries, are those based upon the primary industries, from which and through which they obtain the materials which they elaborate.

The primary industries stand between man and the bounties of Mother Earth. Without their agency he is like Tantalus of old, and not one drop or morsel can he have to supply his simplest needs.

The primary or exploitative industries are arranged in three groups: *Agriculture*, *Mining*, and *Fishery*—the exploitation of the products of the earth's surface, the products of the interior of the earth, the products of the waters.

In each of these fields of activity there should be fuller knowledge in certain definite directions:

(1) In determining the character and extent of the sources of supply.

(2) In discovering the least expensive and least wasteful mode of bringing the harvest to the consumer or the manufacturer.

(3) In the case of agriculture and fisheries, in preventing destruction of the sources, either by protective restriction or by artificial replenishment.

Of the three the fisheries are most in need of scientific aid. The mines are always under the control of individuals, whose personal interest forces them to be prudent. Agriculture is based upon individual proprietorship, and the improvident and careless farmer or stock-breeder at once feels the results of his own shortcomings. In the fisheries, however, individual wants are lost sight of in individual rivalries, and although the preservation of aquatic animals is a matter of national importance, reckless men with engines for wholesale capture may entirely exterminate the inhabitants of a lake or a river, and almost depopulate the waters of a coast. This may be done without the knowledge of the public, and indeed before the fishermen themselves recognize the consequence of their own improvidence.

The only parallel to this is in the destruction of the forests, in which individual owners may cause national disaster. The lumberman, however, is checked in his work of destruction to a greater degree than the fisherman, for his operations, being visible to all, are more subject to control by public opinion.

It appears, then, that one of the most potent of all motives—self-interest—affects two classes of industries in directions which are diametrically opposite. For agriculture and the mines it is conservative, while for the fisheries it is essentially destructive.

The secondary or elaborative industries—those by which the products of the primary industries are elaborated to supply the manifold necessities of modern civilization—have also need of scientific direction and the application of the most improved methods known in chemistry, physics, and mechanics.

Through the agency of the arts and handicrafts man is supplied with clothing, shelter, amusement, and intellectual occupation, and the great system of accessories and refinements with which these are associated in civilized life. In the conduct of the secondary industries, however, private interest is sufficiently potent to force the men in control to utilize the latest results of scientific discovery, and is strictly conservative.

The importance of securing the aid of science for the solution of economic problems has for the last fifty years been very generally recognized in this country. No better proof can be found than the liberality with which the Congress of the United States, in such matters usually the embodiment of the will of the thoughtful majority, has provided for scientific aid for all the great industries.

In these days of progressive democracy, governments are working more and more for the benefit of the people at large. The founders of our Republic never ceased to insist that the safety of a free government must depend upon the enlightenment and intelligence of its citizens. They understood, also, that its industrial and economic welfare requires the application of enlightened knowledge to the administration of every industry. The whole public record of Washington, Jefferson, Franklin, and their associates bears witness to this.

The mediation of government seems, in a Republic like ours at least, to be essential in order to secure, for the benefit of the people at large, the immediate advantages of the results of new scientific discoveries, which would otherwise be appropriated, for the most part, for the personal profit of limited classes.

It is manifest that all cannot be left to the universities and colleges. Their self-imposed and evidently proper limitations forbid. Indeed there are many wise men who maintain that these limitations should be increased. These insist that the sole duty of a university should be to *teach* universal knowledge. The *increase* of knowledge is, in their opinion, the proper function of an academy of sciences.

Now, academies of sciences exactly corresponding to those of the Old World do not exist on this twin continent of Republics. Such academies remind one of the lordly salmon, of which it was once said that it could only survive in rivers which were under the shadow of a throne. This was before the days of public fish-culture. Academies are associated with forms of society in which aristocratic ideals prevail. Membership is limited, and is a mark of personal distinction. Successful discoveries are rewarded by decorations and titles of honor, by governmental subsidy, even more effective than grants in direct aid of research, and there are liberal appropriations of money as well. Our own academies of science are no less honorable and efficient, but they receive neither money nor recognition from the Government, and though, as in the case of the National Academy of Sciences, often responding to calls for gratuitous advice, are never used by the nation as public agencies for the *increase* of knowledge.

The real analogues under our Government of the European academies of sciences are the scientific bureaus, whose officers are the salaried agents of the nation.

A scientific investigator, working in his own laboratory, directs his studies in the channels most agreeable to himself. If not influenced by the need of money-getting, he will, as a rule, pursue some branch of *pure science*, for the love of knowledge or in the hope of fame. In the college and university laboratories the tendency is always to seek for the discovery of principles rather than to make economic applications of those already familiar—to the pursuit of knowledge for its own sake.

Universities do not often encourage or even tolerate studies in applied science, for the reason that these are not so well calculated to direct the minds of their students to the highest intellectual ideals. It is well that this is so; for our universities by their work in pure science have rendered possible almost all which has been done in economic science, and have done far more for the material advancement of the world than they could have done with more practical ends immediately in view.

The attitude of a government when it subsidizes scientific workers is always more or less sordid, and as unlike as possible to what we desire to believe to be the spirit of science itself, as it is cultivated in the universities. We should be grateful, nevertheless, for evidences of liberality wherever they are manifested, and supremely thankful that our law-makers rarely object to allowing work of a scientific character to be done when there is reason to hope that it may ultimately serve as a foundation for economic applications.

A very wholesome condition is manifest in the confidence which is shown in the scientific bureaus, both by the heads of the Government and by the people. Questions of politics have never been considered in the selection of the scientific officers of the Government so far as the National Government is concerned, and the advice of the universities and the scientific men has always been sought and regarded. I speak from the observations of twenty years' residence in the National Capital. Once selected, these officers are held responsible solely for the results of their work, and have only been criticised in the rare instances where, after long waiting, adequate results have seemed to be lacking.

The confidence of the people is quite as remarkable, and to this may be ascribed much of our national industrial welfare. When perplexities arise in any industrial enterprise, through lack of knowledge or experience, it rarely happens that the aid of science is not invoked, and in the case of the primary industries at least it is usually a Federal or State scientific bureau which is the agency selected.

I read not long ago an editorial in the London *Athenæum* in which it was said that there is not a department of the British Government to which a citizen had a right to apply for information upon a scientific question. This seems hard to believe, for I cannot think of any scientific subject regarding which a letter, if addressed to the scientific bureaus in Washington, would not receive a full and practical reply. It is estimated that not less than 30,000 such letters are received each year. The Smithsonian Institution and National Museum alone receive about 10,000, and the proportion of these from the new States and Territories, which have not yet developed institutions of learning of their own, is the largest. An intelligent question from a farmer on the frontier receives as much attention as a communication from a royal academy of sciences, and often takes more time for the preparation of the reply.

One source of this public confidence is the fullness of the annual reports of the several bureaus and the extent of the editions for general distribution. These reports contain not only the results of the year's work, but appendices which illustrate the methods of work, and then, taking the reader into confidence, show him the manner in which conclusions are reached. It would be a national misfortune if the protests of specialists and book-dealers were to result in reducing the editions of these reports. The 500,000 reports annually sent out from the Department of Agriculture are none too many, and the waste of an inconsiderable percentage of them is of no moment when the enlightening effect of the whole is properly estimated.

The government of the United States does nothing for our manufacturing interests, save to collect their statistics, protect them against foreign competition, and gather information about foreign markets through the consular system and the Bureau of American Republics. It has however provided for the primary industries—agriculture, mining, and fisheries—with great liberality and with an amount of intelligence which is even more noteworthy.

The interests of agriculture are attended to by a bureau which, after a consistent and wholesome growth of three decades, has attained to the rank of a Department, and which receives for the current year an appropriation of three millions of dollars. The plan of this Department is to place at the disposal of the farmer all the results of the sciences, and when necessary to apply them for his benefit, as is done in the Weather Bureau. It makes new discoveries and shows how old ones shall be applied, and it publishes information broadcast throughout the land. In further prosecution of its plans the government aids each State government in maintaining a local center of investigation and education, appropriating for this purpose about seven hundred thousand dollars for the current year, which is supplemented by an equal or greater annual expenditure on the part of the several State governments.

For the benefit of the mines we have the Geological Survey, the history of which extends over a period of nearly twenty-five years, during which it has made a consistent and healthy growth. Its work is of the utmost importance, not only to the mining industries but to agriculture as well—an importance which will be much greater in the years to come, when the surface supplies shall have become depleted. In this work, too, the general government is seconded by the State governments, many of which have local agencies of their own. With comparatively few exceptions, all the scientific geologists of the country are engaged in the official surveys, either of the government or of the States.

Ten years ago, in a paper upon "The Status of the U. S. Fish Commission in 1883," I took occasion to quote the opinions of scientific experts in all parts of the world, in criticism and commendation of the manner in which the problems of fish-culture were treated, as illustrated at the International Fisheries Exhibition in London. The displays of the United States in Berlin in 1880, and in London in 1883, resulted in a complete change of public policy throughout Europe; for on those occasions the world saw demonstrated the essential distinction between private and public fish-culture. Private fish-culture is, like poultry-raising, a field for individual effort with private capital, for purposes of personal gain. Public fish-culture has to do with the preservation and renovation of the great source of public supply—a field to be compassed in part by the States, but in its broader developments only properly covered by national or international enterprise.

Public fish-culture, as now known, in Europe, Asia, Australia, and America is actually the result of the liberal policy of the Government of the United States in securing, for the national good, scientific talent of a very high order.

The problems of fisheries and fish-culture require, more particularly than those in any other field, the skill and experience of trained scientific investigators.

The miner and the agriculturist have to do with phenomena which are visible and tangible. The culture of terrestrial plants and animals is comparatively simple, because they are affected by changes in climate and temperature which we ourselves feel and appreciate. The fisherman and the fish-culturist, on the other hand, have to do with living organisms, whose presence and movements are uncertain and often seemingly mysterious, and which exist under conditions which he can understand only after they have been interpreted for him by science.

The study of these difficult problems has drawn to it many great naturalists, among them such men as Duhamel du Monceau, Agassiz, Vogt, Huxley, Quatrefages, Coste, Von Siebold, and Baird, and the greatest of these was Baird.

I wish I could properly eulogize the wise, the judicious, the practical plan of work which was devised by our first National Commissioner of Fisheries, when he entered upon his duties in 1871; then the results, as partly reviewed by himself in the last year of his life, in his paper on "The Sea Fisheries of North America," posthumously published, or in his later reports to Congress, and also in the volumes on "The Fishery Industries of the United States," in which the members of his staff endeavored to summarize the knowledge which had been developed under his direction. Time will not permit me to do this, and it is unnecessary, for the results are familiar to you all.

I should be glad, also, to take up the achievements of the National Commission during the past five years and to point out how success has been achieved in all lines of work previously decided upon, while new paths have been laid out in the light of new results which have been attained.

After all, what more can be said than that it is living up to the high ideals of its founder, the illustrious Baird, and that it has never failed to meet the constantly increasing demands upon its resources, whether in the field of science or in that of practice, and that it is one of the best examples of the way in which science may be utilized in behalf of a great industry.

The work of the State fish commissions also deserves high praise. Some of the States have but a small interest in fish-culture and have not organized the work on a large scale, and some States have done less than they should have done, but taking them together the aggregate of good work is very considerable and well worthy of mention not only in the field of scientific inquiry, but still more so in respect to judicious application of the results of science. The way in which the State commissioners have coöperated with each other and with the National Commission in every department of fishery economics is a noteworthy example of the manner in which the States may work together for mutual good.

The most significant tribute to the American methods is the constant attention which they receive from the rest of the world. Within the past ten years I have seen a constant stream of special commissioners from England, Scotland, and Ireland, from Norway and Sweden, from Germany and Austria, from France and Italy, Russia, Finland, and Siberia, from Australia, New Zealand, and Japan, coming as agents of their own Governments, and devoting months and sometimes even years to the study of the methods employed by the Nation and the States, and on their return embodying these results in official reports which are full of praise and approval.

In the application of scientific research to the problems of the fisheries and fish-culture, the duty of the United States in the future appears to be very manifest. The National and State Commissions must be strengthened and encouraged to carry out to the fullest extent all legitimate lines of investigation. Their work will not be ended until the following results shall have been accomplished:

First. There should be a complete physical and biological survey of every hydrographic basin and every mile of coast upon the continent. The survey of the coast begun by the United States Fish Commission in its first year is still being carried on with admirable results, and too much cannot be said in praise of the thorough system of exploration of the various river-basins established by the present Commissioner.

Second. We should attain to an understanding of life-histories (including the embryology) of all aquatic animals of economic value, and of the animals and plants with which they are associated, which may be directly or indirectly beneficial or injurious. This work, too, has been carried rapidly forward by the Federal and State commissions and by many of our colleges, and, although much remains to be done, the mass of information accumulated and assimilated within the past twenty years has been one of the most important factors in bringing about recent advances in fishery economics.

Third. There should be an understanding of all physical and biological problems involved in the practical work of artificial culture. Here, too, there has already been an advance of great magnitude, especially in America; and the forms of apparatus for fish breeding and transportation, devised in this country under the eye of experts in the various mechanical sciences and with the advice of the biologists, have replaced almost without exception those in use twenty years ago.

Fourth. The results of past scientific inquiry should be made effective by framing a consistent code of Federal and State laws for the protection and preservation of the sources of fishery supply. It is doubtful whether such a code exists in any part of the world, and it may be that the time has not yet come for framing it, but I should regard the adoption of a wise and effective law and its successful application as a supreme test of the wisdom of our public men and their scientific advisers.

Fifth. All depleted waters should be repopulated with fishes in their former abundance, or in even greater plenty than at the time of the discovery of America, and unproductive waters must be thoroughly stocked.

Sixth. A school should be established for training fishermen, fishery administrators, and fish-culturists, and (with the coöperation of the universities) of biological investigators. Such a school might be established in the great laboratory building erected by Professor Baird at Woods Holl. Here, at slight expense, might be maintained one of the principal biological establishments and the greatest fishery school in the world. Norway and Sweden, Japan and Germany, have schools for fishermen. England, France, and Holland maintain biological laboratories; and these and almost every nation in Europe contribute to the support of the great International Zoölogical Station at Naples. Why should not our Government, with the coöperation of the

States, maintain a great central establishment of this kind, to do for the fisheries and the sciences upon which they depend what agriculture and agricultural science have had done for them by means of the forty-nine agricultural experiment stations and the almost equal number of agricultural colleges with which they are connected?

Seventh. We should create a national association, after the model of the *Deutscher Fischerei Verein*, in which fishermen, fish-culturists, legislators, social economists, and philanthropists may work together to develop enlightened public opinion and to promote the interests of the nation and of mankind in this department of human activity.

If all these ends shall be attained for the fisheries, and the work of the Government for agriculture, forestry, and the mines shall be carried to equally abundant and beneficent results, we may then feel a just pride in the ability of our Republic to make its public institutions serve the economic interests of the people.

9.—BIOLOGICAL RESEARCH IN RELATION TO THE FISHERIES.

BY JOHN A. RYDER,

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There is no longer any questioning the fact that when we consider the economic relations of one organism, the economic relations of multitudes of others are at once involved. It may be that those others, thus brought under consideration, may, as single individuals, be of no appreciable economic value to man; only when very minute beings are gathered together in great numbers by other and useful organisms as their staple of nourishment does their value become palpable. For example, a very large and widely distributed group of plants found in fresh and salt water, the diatoms, are very minute as individuals. Some of these diatoms have long been used as test-objects in the trial of the power of resolution of the object-glasses of microscopes. By many amateurs in science this is supposed to be their sole use. The botanist, however, finds in them a wonderful exhibition of the power of a very minute simple organic type to manifest the most manifold variations of the form and superficial sculpturing of its siliceous envelope. To the economist and fish-culturist the diatoms have a totally different significance. Probably more than one-half of the food of the oyster consists of these minute vegetable organisms. Therefore, one-half of the sapid parts of the oysters used as the food of man represents an equal volume of minute organisms transubstantiated into the flesh of this bivalve. These almost infinitesimal vegetable motes that swarm in the sea-water, wherever oysters thrive, are integrated into oyster-flesh by the milliards by means of the wonderful processes of prehension and assimilation manifested by this mollusk. An indefinitely little and apparently useless organism is thus aggregated and transformed so as to build up by infinitesimal increments another palpably large organism that is useful and valuable to man as food. The oyster, as one part of the harvest of the seas, is in reality largely a harvest of these apparently useless diatoms transformed into something useful.

Oysters that are found in different places differ wonderfully in their rates of growth, conditions of flesh, etc. Why should this be so? It is hardly to be doubted that these differences in the growth and conditions of oysters at different places is correlated with the character and abundance of their food supply. If this is true, the kind and relative abundance of diatoms must be studied at these different places if we expect to find out the causes of the differences in flavor and quality of oysters from different beds. We are thus brought to realize the fact that the scientific and accurate study of an apparently useless minute organic type has direct and useful bearings upon the production of an important element of food supply. The very existence of oysters in a given locality is therefore dependent upon the abundant production of a few types of microscopic organisms at that place. Whatever, therefore, impairs the power of these minute organisms to reproduce themselves in such places must impair the productiveness of the oyster beds in the same situations. It is also obvious that, if we would most profitably study the welfare of the oyster beds on our coasts, we shall be obliged to consider the conditions of life under which this microscopic oyster food is produced.

Similar relations are sustained by many other large aquatic to other microscopic organisms. For example, it has been shown by the writer that the food of the sturgeon, during its larval life, is microscopic. In fact, were it not for this capacity of the larval sturgeon to obtain other living organisms of small size, it could not reach those stages of growth at which it is possible for it to feed upon larger organisms, and thus be enabled to reach the adult condition. In short, were it not possible for the very small larval sturgeon to find living forms small enough for it to capture and swallow entire, it would not be possible for it to grow to those stages which lead to the adult state. We thus realize that were there no microscopic organisms there could be neither caviare nor smoked sturgeon.

The same is true of the larval oyster. It is exceedingly probable that were there no bacteria and monads still more minute than the diatoms upon which the adults feed, the very young larval oyster could not find living food small enough to pass into its exceedingly small mouth. The lowest and minutest organisms known, therefore, probably enable the very young oyster to pass into the next larger stages of growth, and thus absolutely secures this important mollusk against extinction. The bacteria and monads seem, in fact, to be a kind of baby food for young oysters that enables them to pass the critical stage of their very young infancy with safety. Bacteria should therefore not always be condemned. In the form of the yeast plant, and as the bacterium of the butyric ferment, microscopic organisms may be vitally concerned in the production of bread and butter, no less than in the production of oysters. While some bacteria, such as the cholera *Spirillum*, may be an agency concerned in decimating the human family, other harmless species may be the means of indefinitely continuing the supply of the necessaries as well as the luxuries of the tables of mankind. It may not be amiss to remind an all too thoughtless public that, whether one enjoys an after-theater supper in a splendid restaurant or a modest oyster "stew" at a cheap lunch counter, the despised bacteria may be indirectly the means of ministering to the mere enjoyments of the palate as well as the necessities of existence.

The same is true of still more costly luxuries. Were there no microscopic organisms upon which the larvæ of the pearl-oyster could feed to carry them over the critical stages of their infancy, there would be no pearls to ornament the show loving human animal, since there would then be no true pearl-forming animal to produce those gems.

Coming to more prosaic and useful things, the fish-oil used in dressing leather, in like manner, is largely the accumulation of the oleaginous matters once forming part of the bodies of microscopic organisms, upon which oil-producing fishes and cetacea feed. Dr. Peck has lately shown that the much-abused menhaden, from which oil and guano are produced, is a living filter that literally strains all its microscopic diatomaceous and protozoan food out of the waters of the ocean wastes that it inhabits. The oil-producing basking-sharks do the same. Whales that may produce upward of two hundred barrels of oil live exclusively upon small pelagic organisms that must themselves live upon still smaller ones. A single whale was found by Mr. Edwards to have made its last meal upon shrimps, of which several barrels were taken from its stomach. These shrimps had fed upon still smaller creatures that had been feeding upon the microscopic life of the sea. Infinitesimal volumes of food are thus gathered together in ocean wastes and assimilated in succession through a series of organisms gradually increasing in dimensions, man at last reaping the benefits of their industry, incident to the struggle for existence, in the pursuit and capture of prey as food.

In this way it may be shown that on every hand we are vitally dependent upon the lower worlds of life. Even the beefsteak that is to-day being transubstantiated, as the case may be, into either the clown or the sage, may have been part of an animal that was feeding a week ago upon clover that was partly supported with nourishment from the soil by the intermediation of bacteria. The interdependence of the large and the very small forms of life seems to be almost universal. There is such a thing, therefore, as biological economics, as well as a specific human political economy.

Other microscopic marine organisms, such as the foraminifera, have been in the past and are still engaged in world-building. Strata of the earth hundreds of feet thick and thousands of square miles in area are the products of the agglomeration and deposit of the skeletons of untold myriads of these microscopic organisms that once lived in the oceans of the past ages of the world. Of the rocks so formed the Pharaohs built the pyramids to serve as their tombs. The "bones" of microscopic organisms have thus been made to enshrine the bones of men. Some organisms of this same group, at the present time, furnish a part of the living food-supply not only of existing surface fishes, but also of those found at great depths, as I have found.

In every age do we find, therefore, that man has been vitally related to that lower world of life which ranks so far below him in powers and organization. The modern demands upon the sources of the world's food have not yet impelled investigators to study these microscopic organisms as thoroughly as their importance demands. Some, it is true, as the sources or vehicles of human disease, have been carefully studied, thanks to the inspiration of the genius and patience of Pasteur. The fact, however, that this ubiquitous microscopic life is one of the most important of the ultimate sources of the food supply of the world, is only beginning to attract the attention it deserves. The minute forms of life in their bearings upon the interrelations that subsist between the larger and higher forms of life have hardly yet been seriously considered. Even the life-histories of the great majority of the microscopic forms of life are not fully known. Even the relative abundance of the different species of protozoa and protophyta in the ocean, is not known; nor is it more than approximately known to what extent temperature and ocean currents affect their rates of multiplication, and consequently their abundance and distribution. In a large proportion of cases, also, we are ignorant of the nature of the food of many large marine and fresh-water species of great economic value. Again, we do not know to what extent animals that are of no economic value prey upon those that are; or, to what extent useless forms rob useful ones of the microscopic food upon which the latter subsist. Since it is also a fact that the young or larvæ of many useful animals are very minute, as the oyster, for example, it is not known to what extent such minute young stages of useful animals are preyed upon by useless animals. I have found the entire contents of the alimentary canal of a useless mollusk to consist of the remains of the minute young stages of other mollusks, to the number of many thousands, that may have been the embryos of useful species. Nor, again, is it known how many microscopic organisms are hurtful or poisonous to large ones that are useful to man.

It is perfectly evident, then, that the field for research in this branch alone of biological economics is almost unlimited. Its cultivation would achieve most startling and valuable results. Many of these results would be found to have the most unexpected economic and scientific applications. In fact, the thorough investigation of the biology of the lower and minuter forms of life would probably disclose many hints of the method of the origin of life itself, to say nothing of the practical value of such inquiries. It would also disclose hints as to the methods of operation of the process of organic evolution or the transformation of species. It is opportune for naturalists all over the world to protest against the manner in which the study of the simplest forms of life is dealt with in many of our colleges and universities. No sound conceptions of the nature of the processes of life in the higher organisms can be obtained without a study of those of the simplest ones. Nowhere else do the processes of life present such simplicity in contrast with the appalling complexity of the life processes of the higher types. Nowhere else do we find it possible to so closely approach nature by way of experiment, to inquire what life is and what is the nature of its ultimate machinery. Nowhere else can we hope to get such prompt reactions when these minute beings are subjected to the action of drugs. Whether very dilute deleterious chemical bodies when brought into relation with such microörganisms produce their effects by dynamical and chemical agencies, or by means of endosmosis only, would have profound bearings upon therapeutics and might be the means of laying the foundations of the scientific principles of that science. This we assume to be probable because the higher organisms are composed of aggregates of bodies, the so-called *cells* of their tissues, which are, taken singly, the morphological equivalents of the unicellular microscopic forms of life.

The steps by means of which the infinitely little and seemingly useless beings are integrated or developed into the indefinitely great and useful can be understood only through prolonged observation and experiment. Germany has made a scientific beginning in the study of the minuter as well as the greater life of the sea. America can not afford to lag behind with the splendid equipment already in her possession in the laboratories and vessels of the U. S. Fish Commission, which could be made a hundredfold more efficient than at present if the enlightened policy and aims of Commissioner McDonald could be carried out. If an adequate permanent endowment could be had for the great Government laboratory and hatching station at Woods Holl, Mass., researches of the most far-reaching and valuable economic and scientific importance could be conducted throughout the entire year. Here specialists, such as physicists, chemists, biologists, morphologists, and physiologists should be employed on the great economic and scientific problems presented by the fishery industries. Here the sea, the mother of the primæval life of the world, is accessible under the best conditions. Here what still survive of the primæval types can be had. Here the processes of the development and survival of the useful species could be studied in a way never before approached.

Here, also, there would be the stimulus of research work that exists nowhere else in America, since the Marine Biological Laboratory, close by, has been so successfully developed by Dr. C. O. Whitman and his associates. Climatal, faunal, and other conditions coëxist that render Woods Holl probably the most advantageous locality for these purposes that could be found on the eastern coast of the United States. An endowment of one million dollars could not be more wisely bestowed than by using it to place the great Fish Commission station at Woods Holl on a permanent basis, with the United States Government as trustee. How judiciously and wisely such a trusteeship has been conducted under the Government is sufficiently attested by the unequaled scientific and economic results achieved under such an endowment and under the administration of the three distinguished and successive secretaries of the

Smithsonian Institution, Professors Henry, Baird, and Langley. As the fostering mother of the most momentous scientific enterprises, from which incalculably valuable economic benefits have been derived for the whole country, that institution stands without a rival on the American continent.

Emerson has remarked that "to a sound judgment the most abstract truth is the most practical." This remark has been frequently verified in the course of scientific progress. The development at the time of apparently useless truths by Faraday, Henry, and others, in their laboratories, has led to the evolution of the most wondrous practical developments in applied electrical science. The same remark holds good in respect to biological research. The seemingly useless facts gathered to-day by the disinterested, truth-seeking biological investigator will, if not to-morrow, become useful next year or even ten years hence. Those of us who have watched the progress of biological research for a quarter of a century can speak with assurance that, in proportion to the complexity of the phenomena and the difficulty of dealing with the subject-matter, biology has made as creditable a showing as any other science whatever.

The very complexity of the phenomena involved and the tedious and patient manner in which results must be awaited are only additional reasons why biological science should receive the encouragement it deserves in working out abstract truths in order to give them practical bearings. The scientific investigation of the interrelations of the members of the aquatic world of life, from the lowliest to the most complex of its form, is what the U. S. Fish Commission has undertaken to do with the all too meager means at its command. Practical results the Fish Commission has achieved under the administrations of Profs. Baird and McDonald. It now remains to increase the efficiency of that work by adding to its duties, as desired by the present Commissioner, those of pure research under endowment, so that the great laboratory, in connection with the hatching station at Woods Holl, can be made productive for the entire year instead of only for a few months out of the twelve.

We might then begin to hope that the foundation for a theory of the economics of ocean life would be laid, since, with the unequaled facilities for the study and capture of the life of the surface and bottom of the sea, possessed by the Commission, a vast system of organized research might be conducted that would be beyond anything in value yet undertaken by any country of the world. With abundant means to defray the expense of the costly illustrations and experiments incident to the work, such an establishment would be an enduring monument to some generous, liberal-spirited donor. Such a system of biological investigation in connection with the many stations possessed by the Fish Commission all over the country might be made the most comprehensive in existence. As shown at the outset of this paper, it is a knowledge of the life-history of the seemingly useless and infinitesimally small forms that must lie at the foundation of a knowledge of the growth and development of the useful and practically valuable forms of life. It would, therefore, seem that no stronger argument should at this late day be needed in behalf of the utility and wisdom of an extension of research in connection with the fishery industries of our country. Will some generous friends of science permanently link their names with one of the grandest enterprises and opportunities of modern times? It would be most fitting if the fifth century of the Columbian era might witness the permanent establishment of a great biological laboratory on our coast, the sole business of which would be to foster research and economic study in relation to the fisheries of our country.

10.—ON THE INFLUENCE OF LIGHT ON THE PERIODICAL DEPTH-MIGRATIONS OF PELAGIC ANIMALS.

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As is now well known, the animal life in the ocean and of fresh-water lakes is confined chiefly to two regions, one extending from the surface of the sea to a depth of about 400 meters, the other being the ground region of the ocean. We know, moreover, that a good many of the surface animals migrate periodically in a vertical direction, coming up to the surface during the night and going downward during the daytime, but not deeper than 400 meters. For the physiologist the question arises what determines this peculiar vertical distribution and periodical migration of marine animals. My investigations concerning the effects of light on the motion and orientation of animals made it certain that this periodical depth migration of sea animals is determined to a certain extent at least by the light. In order to make this clear I must give a short sketch of the way in which the light determines the orientation and motion of animals.

You all know that many animals, like the moth, for instance, go towards the light. It was believed that this was due to an attraction of the animals by the light, or at any rate that these animals liked the light; other animals show the opposite reaction, they go away from the light, and it was generally believed that these animals were fond of the dark. My experiments, however, showed that these reactions are the outcome of a purely mechanical effect of the light upon the animal, and that the animal, as a rule, is neither fond of the light nor of the dark. The light forces the animal to orientate itself in such a way that its symmetry axis or symmetry plane falls into the direction of the rays of light, and consequently all symmetrical elements of the surface of the animal are met by the rays of light at the same angle. There remain two possibilities: The animal in this orientation can turn either its oral pole or its aboral pole toward the source of light. In the former case I have called it positively, and in the latter case negatively heliotropic.

In the case of animals which are fixed to the ground, like hydroids, for instance, the only effect of the light consists in this orientation of the animals. But in the case of animals which are free-moving, like insects or copepods, the animal is orientated by the light, and is forced to move in this orientation. The consequence is that if the animal is positively heliotropic it must necessarily move straight toward the light. If the animal is negatively heliotropic it must move straight in the opposite direction. That the motion of the animal is determined by the direction of the rays of light, and not by the differences in the intensity of the light, can be very easily shown. Positively heliotropic animals, like plant lice, move towards the source of light even then, if by certain experimental arrangements their path goes from lighter to darker places; and negatively heliotropic animals go from the light even then, if measures are taken so that their way leads them from the dark to the light. But in both cases the animal migrates in the direction of the rays of light. An illustration will show this influence of the direction of the rays of light better than a long theoretical explanation.

Spirographis spallanzani, a marine annelid, lives in a tube which it fastens to the ground. The tube is not transparent and only the tentacles of the animal, which project from the tube, are exposed to the light. The tentacles are arranged in a circle. If we put these animals into an aquarium in which the light falls in from only one side the animal bends its tube in such a way that the symmetry axis of the circle of tentacles is parallel to the direction of the rays of light. As long as we do not change anything in the direction of the rays of light which strike the animal, it does not change its orientation, but as soon as we cause the light to fall into the aquarium from another direction the *Spirographis* changes the direction of its tube so that the symmetry axis of its tentacles is again parallel to the rays of light. Whether the intensity of the light is great or small, whether we use direct sunlight or diffused daylight, the result remains the same.

The larvæ of *Limulus* at a certain period of their life are negatively heliotropic If we put such larvæ into a glass dish and place it near a window through which the rays of sunlight fall in obliquely, the *Limuli* migrate with mathematical exactness in the direction of the sunlight away from the window as far as the sides of the dish allow them to go, and then they remain at rest. If, however, we turn the dish 180 degrees around its vertical axis the animals move again in the direction of the rays of light going away from the window. It is not possible to give you here a full account of the experiments by which it can be proved that the direction of the rays of light alone determine the direction of the motions of the animals, nor is it possible for me to give you here the theory of animal heliotropism. For both I must refer you to my former publications. I only wish to show how this heliotropism determines the periodical depth migrations of pelagic animals.

It is known that the nauplii of *Balanus* appear at the surface of the sea at night and go down during daytime to a depth of 60 fathoms and more. Groom and I found that the nauplii of *Balanus perforatus* show a very peculiar heliotropism. They are positively heliotropic when the light is very weak; but when they are exposed to strong light they very soon become negatively heliotropic. This explains the periodical migration. In the evening, and very often during the night, the light which is reflected from the sky is very weak, and in this light the nauplii are positively heliotropic. As only the vertical components of the rays of light can take effect, the horizontal ones annihilating each other, the animal is forced to move vertically upwards to the surface. At daybreak, as soon as the light becomes sufficiently intense, the animal, by the influence of the light itself, becomes negatively heliotropic and must go vertically downwards. But why does it not go to the bottom of the sea? You know that the water absorbs light and the deeper we go downwards into the ocean the less the intensity of the light becomes.

Investigations of Forel and others have shown that at a depth of about 400 meters below the surface the intensity of the light is already so small that on a bright day it hardly affects longer the most sensitive photographic plate. Thus the nauplii which, under the influence of intense light, have become negatively heliotropic on their migration downwards, very soon must reach a depth where the light is so weak that they become positively heliotropic again, and necessarily must begin to move upward. But as soon as they come back into stronger light they become negatively heliotropic, and must go downward again, and so on. So it happens that these animals, by the influence of the light, have to migrate periodically—during the night toward the surface, during daytime downward, but no deeper than 400 meters below the surface.

Later on, at Woods Holl, I tried to find out whether it was not possible to make other pelagic animals at desire positively and negatively heliotropic. I found that this could be done easily in copepods and larvæ of *Polygordius* in different ways; for instance, by the influence of the light itself. Direct sunlight made positively heliotropic larvæ of *Polygordius* negatively heliotropic within one or two minutes, but only as long as the temperature was above 10° C. In these experiments great care was taken to keep the temperature of the animals constant. But when the temperature of the water in which the animals were kept was brought down to 7 degrees or less the most intense sunlight was not more able to make the animals negatively heliotropic. On the other side, at a temperature of about 30 degrees, the animals remained permanently negatively heliotropic, even in the weakest light. I found similar phenomena in copepods. These facts, it seems to me, must have some bearing upon the depth migration of sea animals. At the surface of the Mediterranean, for instance, the temperature rises to a considerable height in summer. The consequence is that animals of a similar heliotropism, like the larvæ of *Polygordius* or copepods, can not more come to the surface even at night, for the high temperature at the surface makes them negatively heliotropic even toward weak light, which in winter time would make them move towards the surface. But on the other side it is clear that these animals can not go down to the bottom of the sea. The temperature of the water decreases with increasing depth, and as soon as these animals on their migration downward come to water which is sufficiently cool they become positively heliotropic again and now have to go upward; but this brings them back to warmer water, where they become negatively heliotropic again, etc. The investigations made at the zoölogical station at Naples have shown, indeed, that certain pelagic animals which in winter come up to the surface during the night, in summer always remain at a certain depth below the surface. These few examples may suffice to show how the light can determine the periodical depth migrations of pelagic animals.

It is unnecessary to say that it is impossible to exhaust this subject in so short a time. But in order to prevent misunderstandings I must mention that I do not believe that light is the only physical influence which determines depth migrations of sea animals.

As I have shown in former papers, gravitation, for instance, coöperates with light to bring about these periodical depth movements of pelagic animals as well as the constant distribution of sea animals.

It has been found that the jelly-fish which had been carried by the Gulf Stream from our latitude to the region of the midnight sun, continued to migrate to and from the surface in the same periodicity as they did in their former home. In this case I believe the periodical depth migration is due to periodical changes in the amount of water contained in the animal. These changes are due to metabolic processes which, however, are influenced in their periods by the change of day and night. Thus these metabolic changes adapt themselves in their periodicity to the change of day and night and this periodicity remains the same even if the animal later on is carried to the region of the midnight sun.

11.—THE INVESTIGATION OF RIVERS AND LAKES WITH REFERENCE TO THE FISH ENVIRONMENT.

BY BARTON W. EVERMANN, PH. D.

It is the aim of this paper to call attention to the work of the U. S. Fish Commission in connection with the study of the streams and lakes of the country.

The Commission has always held that such investigations as it might properly undertake should have as their ultimate object the discovery of facts and the attainment of results which possess an economic value; and it is believed that all its investigations should be conducted upon scientific methods. Most, perhaps all, investigations possess an economic value when their results and their relations come to be properly understood. Rarely is the importance of any investigation fully comprehended at the time of its beginning. As every one knows, it is a matter of almost daily occurrence that investigations begun as purely scientific studies are yielding results of the greatest economic importance.

So certainly is this true, and so firmly has this important fact become established, that, in the proper conduct of any work undertaken by such a branch of the public service as the Fish Commission, it would seem that the investigations should be comprehensive and thorough, and the method should be the scientific method, the method which has yielded such brilliant results in other lines, the only method by which definite progress is made.

The U. S. Fish Commission is essentially and necessarily a scientific branch of the Government. It was originally established by act of Congress February 9, 1871, for the express purpose of conducting an inquiry into a scientific question where scientific method was demanded, namely: "(1) An investigation into the cause of the decrease of the sea-coast fishes and those of the rivers and lakes, with suggestions as to the best methods of restoring the same; and (2) active measures looking toward the propagation and multiplication of the useful food-fishes, either by restocking depleted waters or by introducing desirable species into new localities."

Thus it is seen that the Fish Commission began as a scientific inquiry whose results, it was hoped, might redound to the good of mankind; and neither its true purpose nor its method has changed.

The problems which properly come within the scope of the Commission are among the most intricate and difficult with which the biologist has to deal, and they are, as individual problems, very numerous, although all more or less intimately related.

For the sake of brevity, let us take it that the proper and ultimate purpose of the Fish Commission is to increase the quantity and improve the quality of the fish food-supply of the United States.

This brings us at once to a consideration of the life-histories of the fishes themselves. We must determine under what conditions each of the various species of food-fishes thrives in its natural state; we must determine the temperature and chemical character of the water in which it is found, the volume or size of the stream or lake, the character of the shores and bottom and the surrounding country; we must also determine what other species of fishes are found associated with it, their abundance and habits; and the same regarding any and all other species of animals and plants found in or about the fish's home. And then, after the determination of the facts regarding the fish's environment, a second and vastly more difficult series of investigations must be taken up, namely, the bearing of each of these facts upon the life of the fish.

The fact is one thing; its value as a factor in the life of the fish is a very different thing. I find a certain species of fish in a stream which has a mud bottom and whose water has a temperature of 60 degrees at noon during dog-days. Am I justified in concluding that a mud bottom and water of 60 degrees temperature are favorable conditions for the growth of that species of fish? Not by any means. In the mountains of East Tennessee last week I saw cornfields on mountain slopes too steep for an ordinary man to climb with any comfort, but I must not infer that steep hillsides are a favorable condition for the growth of corn.

One of the divisions of the Fish Commission, as now organized, is the division of fish-culture. This division has to do with the breeding, hatching, and rearing of various species of food-fishes and the stocking and restocking of different streams and lakes of the country.

To do this work intelligently it must necessarily be based upon a knowledge of the natural conditions under which each species thrives, which of the factors in its environment are essential, which only desirable, which negative, and which detrimental to the best life and growth of the fish. And when it comes to stocking, the division must know the conditions which obtain in every stream and lake which it is proposed to stock.

Another branch of the Commission—the division of scientific inquiry—in addition to its many and important lines of investigation regarding the marine fishes and fisheries, has endeavored not to neglect the fresh-water species. It has undertaken to carry on such a series of comprehensive and exhaustive investigations as will, in time, result in a pretty thorough understanding of all the conditions under which our various food-fishes thrive best and the particular significance of each factor in this best environment.

We have undertaken such a study of the streams and lakes as will enable us to know the peculiar conditions which exist in each important hydrographic basin in the United States.

This, of course, means careful observation and study of all the physical, chemical, and biological features of each stream, for these are the conditions, forces, or elements which together constitute the fish environment, and which determine the presence, abundance, distribution, and condition of the various kinds of fishes found in each particular stream or lake.

Most of the work which has been done so far has been in the line of determining the factors in each environment, rather than guessing what the factors mean. Heretofore great harm has been done by guessing at the facts and also guessing at their meaning. We believe it is much better to be content for the present with the observation and recording of facts, and wait until more facts are in before interpreting their meaning.

As indicating the character and scope of the field work which we have been doing in this line, I shall give the substance of the directions or suggestions which have been furnished for the guidance of the various parties which the Commission has had engaged upon this work. During the last year or two there have been several volunteer observers, and during the present summer six parties were engaged upon field work in accordance with this plan.

Separate outlines were prepared for those parties engaged in lake study and those studying rivers, but in this connection it will be sufficient to give but one of the outlines.

The outline for lake study will serve our purpose, and I give it essentially as it was sent to the field parties, without taking time to put it in better form for this paper, as I perhaps should have done.

In the study of any lake attention should be given to the following:

OUTLINE FOR LAKE STUDY.

PHYSICAL FEATURES.

Geographic position:

Size: Form; greatest length and width and the direction of each; length of shore line.

Depth: Maximum and average; soundings should be made in many different places and the configuration of the bottom determined as accurately as possible.

Temperature: Determine the bottom temperature in various places; also at different depths, say at intervals of 10 feet. At what depth does the temperature of the air cease to affect that of the water? Or, in other words, at what depth does the temperature remain constant? These observations should be repeated once a week if possible and should extend through at least one year. The temperature of the air should also be taken at the same time.

Ice: When and where does the lake begin to freeze, in what direction does the ice spread most rapidly, and when does the lake become frozen over? What places remain unfrozen and what is the cause? Note the thickness and character of the ice from time to time; when and where is the maximum thickness reached? Depth of snow covering ice from time to time. When and where does the ice begin to melt in spring, how and in what direction does it progress, and when does the ice finally break up? Upon what shore and to what extent is it piled up? Is there any regularity in the formation of ice-cracks in different parts of the lake?

Purity: Character of the water, whether clean or muddy, hard or soft; sources and extent of contamination.

Bottom: Whether of sand, gravel, bedrock, or mud, and character in different places. Determine depth of bottom deposit if possible.

Shores: Whether high or low; dry, marshy, or muddy; and of what material made up, as mud, sand, gravel, clay, or rock; geologic age to which outcropping rocks belong; depth and character of drift, if any, in the immediate vicinity of the lake. This can be determined by learning the depth at which bed-rock is struck in the wells of the neighborhood. How do you explain the origin of the lake?

Inlet: What streams flowing into the lake and the amount of water carried by them; temperature, purity, and general character of the water. Locate and note the character of all springs connected with the lake, not omitting any that may be in the lake's bottom.

Outlet: What the outlet is, into what it flows; character as to size, rate of current, and volume of water discharged per minute. Compare amount of inflow with outflow, and make investigations for the purpose of determining the amount of evaporation which takes place from the surface of the lake during each month. This may be approximated by evaporating, in the open air, the water in a large, shallow pan. This, of course, would need frequent repetition.

Obstructions, such as dams, waterfalls, etc., in the outlet, and their influence upon the movements of fish; where fish-ladders have been placed and where not.

Rainfall: Amount for the year; month of greatest and month of least rainfall. Is the lake subject to any changes or fluctuations in level? Does the history of the lake show that it is increasing or decreasing in area?

Winds: Prevailing direction; any relation noticed between this and character of shore? A comparative study of a number of small lakes situated near together would be required in this connection. Direction of wind at time of breaking up of ice in spring. In addition to the observations indicated above, the observer should note any and all other physical phenomena which come under his notice, and which have any bearing whatever upon the lake. Few, if any, observations are unimportant, and every fact observed should be carefully recorded. Many of these observations should be repeated as frequently as possible, and at regular intervals.

BIOLOGICAL FEATURES.

Botanical: Plants found growing in the water, such as water-lilies, sedges, pickerel-weed, cat-tails, water-arum, rushes, arrow-head, pond-weed, water-milfoil, water-weed, eel-grass, chara, etc.; also the smaller forms, such as the various species of algae, duck-weed, diatoms, desmids, etc. The abundance, distribution, and life-history of each should be studied, especial effort being made to determine as accurately as possible the amount of the various kinds of vegetation found in the lake and the area covered by each. Give much attention to the study of the relations which the various species of plants sustain to the animal life of the lake. In studying the life-histories of the various plants, the observations should be as complete as possible, paying attention to their growth from first appearance in spring, through flowering and fruiting to time of dying. What becomes of the dead plants and stems—do they sink to the bottom and decay, or are they drifted upon the shores?

Shore vegetation, including plants growing in or near the water's edge; trees and bushes whose branches overhang the water more or less, and the bearing of these various facts upon the life of the lake.

Information as to the abundance, character, and distribution of all the species of plants found growing, say within 100 yards of the lake, would be of interest and value.

ZOÖLOGICAL.

Fishes: As to species, abundance, distribution, and condition; feeding habits, upon what the various species feed, when and how they feed; can any estimate be made as to the amount of food required to supply the fishes of the lake. Breeding habits; when the different species spawn; location and character of spawning-grounds; what species feed on the eggs of other species? Migrations and other movements; where the various kinds of fish are found at different times of the day and at different seasons. Diseases; by what parasites affected, to what extent, and at what season; when is mortality greatest?

Size: Observe any and all facts which throw any light upon the average size of the individuals of each species; their age, relation of age to size; at what age they begin to breed. Note any change in color occurring during the breeding season.

What food-fishes taken in the lake; extent and value of commercial fisheries, if any; species taken and methods employed; game fishes of the lake; value of the lake to anglers.

Other animal life found in the lake, such as mollusks, crustaceans, insects, and insect larvae, worms, protozoans, etc., their abundance and distribution; make such observations as you can regarding their habits and study each of these forms with reference to its bearing upon the fish-life of the lake; the relation of these animals to the plants should receive attention.

Animal life found in the vicinity of the lake that may have any bearing upon that of the lake, such as batrachians, reptiles, muskrats, raccoons, minks, and various species of water birds, such as ducks, snipes, gulls, terns, herons, fish-hawks, etc., the abundance and time of appearance and disappearance of each. Make attempts to determine the abundance of any and all animal forms in and about the lake, especially of those forms serving as food for the fishes.

These are by no means all the facts which should be observed, recorded and studied.

That there is great necessity for accurate observation in these matters is evident from the different opinions expressed by different gentlemen regarding the menhaden yesterday. The truth is, we have very little exact information regarding the life-history of the menhaden, and have but little if any more about any of our fresh-water fishes. We possess some facts, it is true, and upon these few facts we have based broad generalizations; but are they warranted by the facts? For example, we know that vast quantities of sawdust and vast amounts of refuse from paper-mills and other factories are let into our streams, and we know, perhaps, that great mortality has occurred with the fishes in some of those streams; but do we *know* that the *one* is the *cause* of the *other?* We *think* that sawdust injures the fish, but do we *know* it?

In conclusion let me say that the whole subject of the relation and interrelation of the various animal and plant forms found in our waters, their action and reaction upon each other, and their relation to the physical as distinguished from their biological environment, is the subject which is demanding investigation and upon whose investigation must depend all important advance in fish-culture and fishery legislation.

12.—THE HABITS AND DEVELOPMENT OF THE LOBSTER, AND THEIR BEARING UPON ITS ARTIFICIAL PROPAGATION.

BY FRANCIS H. HERRICK,

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Wanton destruction has exterminated the wild buffalo of the plains, and indiscriminate slaughter is threatening the fur-seal of the Pacific with a like fate. The oyster beds of the Chesapeake, among the richest in the world, have been brought to the verge of ruin by a lack of foresight and a blind trust in the resources of nature. The same evil has overtaken the lobster, and to-day the fishery is declining. It has already ceased to be profitable in many places, and the size of the lobsters has diminished. Too late, the lesson is being learned, that we can not forever reap the wild harvests which we have not sown. "Where I could catch 500 lobsters in a day twenty-five years ago," writes a lobsterman from Maine, "75 per day is now a large catch." The same complaint is heard from nearly every point on the coast. Fishermen are not inclined to look beyond the demands of the present hour, and men in general regard the ocean as inexhaustible in its animal life, as it is apparently limitless in extent and fathomless in depth, forgetting that marine animals may be as restricted in their distribution as terrestrial forms, and as nicely adjusted to their environment.

Before we can deal intelligently with the problem of protecting an animal from destruction, or of increasing its numbers, it is of the first importance that we become thoroughly acquainted with the habits of the animal in question, with its distribution, with the sources of its food at all seasons, with its method of breeding, with the development of the young, and their habits from the time they leave the egg until they are themselves able to propagate their kind.

Until recently, the lobster, our largest and most important crustacean, economically considered, has been singularly neglected by naturalists, and a review of the various measures which have been suggested or adopted for its protection in different States points very clearly to the value of accurate knowledge. The fact that so important a question as the breeding habits of the lobster should have remained for so long a time a matter of guesswork, emphasizes the need of a thorough investigation of its habits and development.

At the invitation of Hon. Marshall McDonald, U. S. Commissioner of Fisheries, I undertook such a work four years ago, and have since given to it all the time which could be spared from professional duties. During the summers I have enjoyed the excellent facilities for research which are afforded by the U. S. Fish Commission station at Woods Holl, Mass., and in August and September of this year I have been able to extend my observations in the field to the coast of Maine, from Portland to Eastport. There is only time to lay before the Congress some of the most significant and interesting facts in the life of the lobster, and to point out what seems to me the most promising method of directing our energies in the work of its artificial propagation.*

The American lobster (*Homarus americanus* Milne-Edwards) is confined, in its adult state, to a comparatively small strip of the Atlantic Ocean, stretching from Delaware on the south to Labrador on the north, and extending in breadth from the coast line out to a depth of 60 to 100 fathoms.

The adult lobster lives and feeds exclusively upon the sea bottom, which it never leaves of its own accord to any appreciable degree. It does not undertake periodic littoral migrations up and down the coast, like the truly migratory fish, such as the mackerel and cod, but is far more sedentary in its habits. In the spring, however, about the first of May, when the temperature of the sea water approaches 55° F., it begins to move from deeper water towards the shore, and in fall, about October, it retires to deeper waters again when a similar temperature has been established; but these semiannual impulses do not affect the entire number of lobsters in a given locality, since some individuals remain in shallow water in winter and in deep water in summer. Goode believes that the extensive northward and southward migrations of the mackerel are carried on in connection with movements to and from deep water. The same causes, of which the change of temperature is the most potent, probably determine the migrations of both fish and crustacean. It is further possible that in the case of the latter these short migrations are secondarily influenced by the occurrence of the molting and reproductive periods. It is certain, at least, that in most cases the eggs are laid and hatched while the lobster is in shallow water.

As a rule lobsters are taken at a depth of from 1 to 10 or 12 fathoms, from the last of April or first of May until October or November. During the rest of the year they are mostly found in water of from 35 to 50 or 60 fathoms, and some stray out to even greater depths. They seem to move back and forth more or less in a body, though it is by no means certain that this is the case.

The lobster must be regarded, as we have seen, as a relatively sedentary animal, and the fact that it is steadily decreasing at most points on the coast, and that the decrease is the most marked where the fishing has been conducted with greatest persistence, points to the truth of this conclusion. The once famous Cape Cod fishery, which dates back to the beginning of the century, and formerly supplied a large proportion of the lobsters sent to New York City, is now practically extinct. The region is depleted, and it will probably be many years before it can be restocked under natural conditions. Indiscriminate and persistent fishing is certain to end in the destruction of such a sedentary species as the lobster, and it is illogical, in the face of an efficient cause for its decrease, to seek for other causes which are neither known nor understood.

The principal food of the lobster consists of fish, either living or dead, and of clams and mollusks of various kinds. Fish which live upon the sea bottom, like the flounder, doubtless fall a prey to their powerful claws, and I have known the lobster while confined in an aquarium to catch and devour the sea-robin. Lobsters feed chiefly by night, when they are far more active than in the day. They are quite sensitive to strong sunlight, and are often found in the daytime under stones or bunches of seaweed, or lying at the mouths of their burrows. The lobster not only digs up the bottom in its search for shellfish and covers itself with mud in cold weather, but burrows, under some conditions at least, as extensively as the muskrat or prairie dog. This is certainly true of lobsters kept in pounds, where the mud banks are sometimes so extensively tunneled by them from below as to afford but insecure footing to a man. They dig horizontally into the bank to a distance of from 3 to 5 feet, and during the day may be seen lying in their burrows with their long sensitive "feelers," or antennæ, outstretched, ready to warn them of the approach of an enemy, and with their large claws ready to strike a blow should the opportunity arise. If the hole is exposed at low tide they will leave it in summer, but are not so careful to do this in winter, when they are far less active.

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* The detailed work on the Life-History of the Lobster will probably be completed by the end of the coming summer. It will contain a full presentation and discussion of all the facts that are known concerning the habits and general life-history of the adult lobster, the habits of the larvæ, and of the young during their long period of immaturity, and the structure and development of the reproductive organs. The development or metamorphosis of the larvæ from the time of hatching, and their subsequent growth, will be fully described, and the development of the embryo will also be reviewed. The paper will be illustrated with upwards of thirty-five plates.

Next to reproducing its kind, the act of molting is the most important in the life of this animal. The whole body is covered by a chitinous shell, in which salts of lime are deposited, giving to parts of it the hardness of stone. When once formed the shell admits of no increase in size, since it is a dead structure, excreted by the skin below it, and when it is outgrown it must be cast off and replaced by a new and larger shell. The new shell is gradually excreted under the old one, and when the latter is discarded the new shell is soft and flexible, and is easily distended to meet the requirements of growth. The growth of the lobster, and of every arthropod, thus takes place, from infancy to old age, by a series of stages, characterized by the shedding of the outgrown old shell, a sudden increase in size, and the gradual hardening of the shell newly formed. Not only is the external skeleton cast off in the molt and the linings of the masticatory stomach, the œsophagus and intestine, but also the internal skeleton, which consists for the most part of a complicated linkwork of hard tendons. This is rendered possible from the fact that all these structures are derived from infolded portions of the skin, and in molting they are simply drawn out of their original folds or pockets. It is thus easy to see why the molting period is a critical one.

It requires from two to three weeks to form a tolerably hard shell, and from two to three months to produce one which is quite as hard as that cast off. Since the process of molting involves a long series of changes it is not surprising that a number of names have been applied to lobsters while undergoing them. The terms "black shell," "crack back," or "shedder" are used to designate a lobster which is nearly ready to molt. "Soft shell," "buckle shell," or "paper shell" apply to one which has recently shed, the shell being easily compressed by the fingers. A "hard shell" or "old shell" lobster is one in which the shell has attained, or nearly attained, its maximum weight and strength.

In the final act of molting, which lasted in one case which I witnessed exactly five minutes, the lobster lies on its side, and bending its body, distends the membrane between the "tail" and the shell of the back. This membrane finally bursts, and the front part of the body, the large claws, and other appendages are gradually withdrawn from their old armor, the "tail" coming out last. To aid this process, the lime salts have been absorbed from some of the joints of the legs which carry the large claws, so that the investing shell can be distended to an unusual size, and absorption also takes place along the median line of the back. Notwithstanding this, the tissues of the large claw are stretched out like a stick of candy, and are drawn through an opening at the base of the second joint, the area of which is less than one-fourth that of a cross section through the largest part of the claw. The shell of the back, or carapace, comes off entire, as a rule, but occasionally it is split along the line of absorption and is thus partially separated into two halves.

At the time of shedding a considerable store of lime has been laid down in the walls of the stomach, probably for the rapid hardening of the lining of this organ or of the shell. It is in the form of two glistening white masses, one on either side, and each about the size of a small filbert. These gastroliths, better known in the crayfish as "crayfishes' eyes," figured prominently in the pharmacopœia of the ancients, being much esteemed as remedies for a great variety of disorders. They are largely composed of carbonate and phosphate of calcium, and when the sacs in which they are formed are opened each mass separates into several hundred snow-white rods or columns.

A curious habit which I have lately observed in the case of small lobsters (3 to 5 inches long) which have recently molted, is that of stuffing the stomach with fragments of calcareous matter, such as weather-worn pieces of shells of mollusks. The examination of the stomachs of hard-shelled lobsters of similar size has not shown any such remarkable assortment of calcareous materials, and it is possible that in the absence of gastroliths these are swallowed by the young lobster after each molt to furnish the growing cuticular skeleton with lime. It has not yet been determined at what particular period in the life-history of the lobster the gastroliths make their first appearance.

After shedding, the lobster is, for the most part, helpless, except in so far as it is able to elude capture by hiding in seaweed or under stones, and must often fall a prey to fish. One would suppose that they would resort to their burrows at such times, but I have seen no evidence of their doing so. As shedding is the result of growth, which is dependent upon a variety of conditions, molting lobsters are found at nearly all times of the year. For the majority, however, the period of ecdysis is the summer and fall, varying in different localities and in different years. In the eastern districts of the Maine coast the greatest number of soft-shelled lobsters is taken in September; in the western, in July and August. Some are occasionally caught in winter, but are very rarely taken in March, April, and May. Lobsters thus, as a rule, molt in shallow water, but "shedders" and "soft shells" have been occasionally taken from the stomachs of codfish caught in deep water outside. The adult lobster increases its length at each molt by about 12 per cent; that is, by 1 to 1½ inches.

There is no definite limit as to age or size when this process can not take place, since we find adult lobsters of all sizes from the smallest to those weighing upwards of 30 pounds. I have recently examined the large claw of a lobster, said to have weighed when alive 39 pounds, and which must have actually weighed 28 to 30 pounds. It is evident from the thinness of the shell of the claw that it belonged to an individual which had molted within two months from the time of its capture. The claw was 13 inches long and 17½ inches in girth, while its total weight was only 16¾ ounces, including the third joint.

Female lobsters reach sexual maturity when 8 to 12 inches long, possibly a very few when even smaller, a larger number at the length of 9 inches, and the majority when measuring 10 to 12 inches.

Over 100 dissections were made in the summer of 1890 (June 28 to August 19) to determine the period at which female lobsters mature, and to follow out the development of the reproductive organs; out of this number, 25 lobsters, from 9.31 to 12 inches in length, had never spawned; 5 of these were between 10 and 11 inches long, and 6 between 11 and 12 inches. In many cases it was demonstrable that the ovaries of these lobsters could not have become mature in less than two years. It is therefore obvious that the lengths of 9, 10, and 10½ inches, which have been adopted in different States as standards below which no lobsters are allowed to be sold, should be raised, if these animals are to receive the fullest benefit from this kind of legislation.

The eggs of the greater number are laid at a definite period and are attached by a gluey secretion, coming from cement glands* in the legs of the "tail," to the long hairs which garnish these appendages and to the under side of the "tail" itself. They are thus carried about by the female, and protected for a period of from ten to eleven months, when they hatch, and the young which then leave the mother lead an independent, free-swimming life, near the surface of the water.

The number of eggs laid varies with the size of the animal producing them, from 3,000 to 9,000, in the case of a female 8 inches long, to 85,000 in one measuring 16½ inches. This is the largest egg-bearing female of which I have any record. Lobsters 10½ inches long, from Vineyard Sound, produce, on the average, 11,000 eggs.

The law of production may be stated as follows: *The numbers of eggs produced by female lobsters vary in a geometrical series, while the lengths of the lobsters producing*

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* The cement glands, which are responsible for the viscous secretion in which the eggs are bathed at the time they are laid, and by means of which they are afterwards firmly secured to the body, are of microscopical size and occur in very great numbers. They are most numerous on the hinder faces of the second to fifth pair of swimmerets of the female. Each consists of a spherical cluster of upwards of a hundred large glandular cells, which terminate in a central rosette (a peculiar, reticulate structure whose nature I have not determined). In the center of this rosette a small lumen or empty cavity is usually seen. The lumen communicates with the exterior by a very delicate chitinous tube, the duct of the gland. This thread-like duct penetrates the chitinous covering of the swimmeret and opens at the surface by a minute pore. Each gland has a large, nearly central, ganglion-cell, which is connected with the rosette and with the nerve which supplies the gland. Organs of very similar structure occur in great numbers in the appendages about the mouth, particularly in the mandibles, maxillæ, the upper and lower lips (labrum and metastoma), and seem, from physiological experiments, to be sense organs, probably of a gustatory nature. These two kinds of organs, cement-gland and appendicular sense-organ, while agreeing in general structure, give an entirely different micro-chemical reaction. This analysis shows that the organs of the swimming-feet are undoubtedly glandular in their nature, and we must infer either that both kinds of organs are really glands, or that there is a close relation between glands and sense-organs of this particular type.

The cement glands, like the mammary glands of some mammals, are capable of active secretion only at definite reproductive periods, namely, at the time of egg-laying in the case of the lobster. The liquid secretion is probably poured out very slowly, and trickles down the sides of the swimmerets upon their hairs and into the pouch or cavity formed by the folding of the "tail," where we know, by observations made on other crustacea, that the eggs are stirred up by the movements of the swimmerets until they become effectually "varnished" and fixed in place by the cement substance. This is not viscous at first, and it is probably some hours before it becomes very tenacious. An interesting case of a lobster which had laid her eggs in the well of a fishing smack came to my notice this summer at Rockland, Me. The lobster was taken out of the well and laid on deck, when the newly laid eggs began to flow out from under the "tail." The crayfish has often been found with the eggs in a similar condition. After a longer contact with sea water the liquid cement becomes, as is well known, very tough and inelastic, resembling chitin in its general appearance and properties.

these eggs vary in an arithmetical series. According to this law we should have the following:

Lengths (in inches)	8	10	12	14	16
Numbers of eggs	5,000	10,000	20,000	40,000	80,000

An examination of nearly a thousand cases shows that the first three terms of these series express very closely what actually occurs in nature. The data are not sufficient for carefully testing the fourth and fifth terms, but the largest number of eggs obtained suggests that there is a tendency to maintain this high standard of production, even at an advanced stage of sexual life. I believe that the law formulated above expresses very nearly the propagative powers of the lobster during the height of its sexual activity, though it is not to be supposed that the latter conforms uniformly to any arithmetical standard.

Fertilization is effected on the outside of the body of the females by means of sperm cells which the male discharges during copulation into a seminal receptacle. This is situated on the under surface of the female, on the middle line, between the basal segments of the third pair of walking legs (fourth pair of pereiopods) and may be opened with a knife by pressing the elastic sides of its median aperture. The peculiar grooved legs of the first segment of the tail of the male are probably inserted into this pouch in copulation, but nothing is definitely known of the process. The spermatozoa are discharged in masses, embedded in a translucent jelly, which is secreted in the glandular section of the seminal duct (by spermatophoral glands). These packages of sperm cells are the spermatophores. The sperm cells of the lobster, when they leave the testis, are provided with three long, slender processes, which radiate from the constricted neck of the cell and are perfectly rigid. It is possible that the function of these processes is to hold the sperm cells together in masses, in the spermatophores, until they are deposited in the seminal receptacle. Here the spermatophores become disorganized, and the sperm may then be easily pressed out in a semifluid, grayish mass. The rigid processes, which would be an impediment to the translation of the sperm, have become relaxed, bent up, and in some cases have disappeared. The way in which the spermatozoa reach and penetrate the eggshell and coöperate in fertilization is unknown.

A female lobster, which laid her eggs July 1, 1890, was kept under observation at the Fish Commission station at Woods Holl 335 days, until June 1, 1891, when the eggs had begun to hatch. The hatching of the eggs begins there in May and extends into July, but the greatest number are invariably hatched in June. I am informed by Mr. Nielsen, superintendent of fisheries in Newfoundland, that the eggs are laid there from the first week in August to the latter part of September,* and that the greater number are hatched from the 15th or 20th of July to the 20th of August. He also states that he has hatched some eggs in floating incubators as late as November.

On the southern section of the coast of Massachusetts the eggs are laid in June, July, and August. In some seasons the greater number are extruded during the latter part of June and the first part of July, in others in the last of July and the first of

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* In the Annual Report of the Newfoundland Fisheries Commission for 1892, Mr. Nielsen states that "the principal spawning time of the lobster, in Newfoundland waters, extends over a period of from 25 to 30 days, from the 20th and 25th of July to the 20th of August," and also that "the ova on the majority of the berried lobsters do not begin to hatch in any considerable numbers before the first week in August."

August, and in others again in August. On the eastern coast of Maine the period of egg-laying probably extends into the first part of September and in Newfoundland and Labrador possibly even later. The exact determination of this period for different sections can only be made after more material has been collected.[*]

Development can be hastened by artificially raising the temperature of the water, but it is not yet known if any advantage would attend this practice. Bumpus has suggested in his paper on the embryology of the lobster (Journ. of Morphology, vol. v) that if the young were hatched by artificially raising the temperature of the water during the cold months of the year, and were then liberated into the ocean, they would be certain to escape the attacks of many summer enemies. It is almost equally certain, however, that the young lobsters would find new enemies in winter, and that the indiscriminate destruction by storms, which must be very great at all times, would then be enhanced.

The female protects her eggs to the best of her ability, and aërates them by her natural movements in the water, and also by the fanning motions of the legs of the "tail" to which they are fixed. When creeping over the bottom she is careful to keep her "tail" well folded. Owing to the unequal development of the individual eggs the hatching of a brood occupies upwards of a week. After hatching, the young receive no fosterage, but are immediately set adrift.

At the time of hatching, the embryo not only gets clear of the egg membranes, but molts and enters upon the first stage of its larval life. This first molting, which occurs at the time of hatching or shortly after it, is very critical, and the failure to accomplish it successfully is the cause of death to a considerable number which are hatched artificially at the Woods Holl Station. The young lobster, just hatched, is about one-third of an inch long. It differs in habits and structure from the adult, but like the latter its growth is characterized by a series of well-marked stages or molts. With each molt it casts off its old shell and assumes new characters until the fourth stage is reached, when the adult characteristics are fairly established. It still, however, swims at the surface, which it continues to do to some extent in the next stage. Its food consists of microscopical organisms which float in the water, and, as at earlier stages, it falls an easy prey to surface-feeding fish. The pugnacious instinct of the young larvæ, and their remarkable activity in killing and devouring each other, invariably attracts the notice of every one who watches them, and is an insurmountable barrier to the successful raising of them in small aquaria.

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[*] Since this was written, I have obtained some new facts which throw light upon the breeding habits of the lobster. Mr. V. N. Edwards sent me some lobsters from Woods Holl, Mass., December 4, 1893, and among these was an egg-bearing female, 12½ inches long, with eggs of a peculiar light yellowish green color. They were in the stage of development which closely follows the egg-nauplius, and probably had been laid about November 1. I have also recently received, through the kindness of Mr. F. W. Collins, a number of specimens of the eggs of the lobster from Maine, which establish beyond question the late breeding of the lobster on the coast of this State. In one individual from York Island, November 15, the eggs were but two or three days old, and in another specimen taken at Cranberry Isle, November 25, the egg-nauplius is barely outlined. In the latter case the eggs were probably extruded about November 10.

The breeding season of the lobster may now be said with certainty, to extend from June to November, and it is possible that it covers even a larger part of the year. This important subject is being carefully investigated, in order to ascertain what proportion of lobsters breed outside the months of June, July, and August, when, without doubt, the greatest number of eggs are laid.

This late breeding of the lobster undoubtedly accounts for much of the obscurity which has hung over its reproductive habits and may also explain the cases of the occasional hatching of lobsters out of season, which have been recorded. Statements have been formerly made that lobsters have been taken with freshly laid eggs in the fall and winter, but they could never be received, because they were not supported by a microscopical examination.

The young larvæ are markedly heliotropic. If the vessel of water containing them is placed in direct sunlight they immediately retreat to the opposite side of the dish, that is, in the direction of the light rays or away from the source of light. If the vessel is rotated through an angle of 180° the larvæ beat a similar retreat, and this may be repeated a great many times. It is thus possible that the young free-swimming stages of the lobster belong to that class of larvæ which leave the surface under the influence of sunlight and swim down to a considerable depth in the ocean, rising to the surface again at night, but it is not known if this is the case, and it may turn out that the young lobster both shuns and seeks the light, under different conditions. This is a point for future experiment to decide.* During the past five summers which I have spent at the U. S. Fish Commission station at Woods Holl we have used the towing net in various parts of Vineyard Sound on bright days, but have never succeeded in capturing the first and second free-swimming stages. It should also be added that but very few of these larvæ were taken at night, and that little towing was done after dusk.

I believe that the scarcity of the young larvæ of the lobster in the surface waters of Vineyard Sound during the summer is due to the fact that they are eaten up or otherwise destroyed. The survival of the young is probably much greater in outside waters than in those sheltered by the land, which are so often the haunts of surface-feeding fish. If this is the case, we may look upon the long free-swimming period of the larvæ as a means not only of securing a wide distribution, but also of a transport from the shore. On the other hand, it is probable that the young lobster, after its metamorphosis is finished, tends to move towards the shore, where it can find a secure hiding-place among the rocks in shallow water.

The fourth larva does not show the same kind of sensibility to light, and is frequently taken at the surface on bright days. I have also dipped from the surface in the daytime a few individuals in the third larval stage. At the fourth stage the larvæ have attained a length of about one-half inch, and have been taken in Vineyard Sound as early as June 29 and as late as August 12, but the majority reach this stage in from fifteen to twenty days. Larvæ have, however, been reared to the fourth stage in the laboratory in eleven days.

Larvæ are never taken at the surface after the fifth stage, from which we infer that they go to the bottom during this period and assume the habits of the adult. At this time the difference between the large claws is not marked, and the first pair of legs of the "tail" is represented only by miscroscopical buds. These and the remaining adult characteristics are gradually assumed during successive molts.

Very little has been known about the habits of young lobsters from 1½ to 3 inches long. I am indebted to Mr. M. B. Spinney for a valuable collection of small lobsters from the shores of Casco Bay and Small Point Harbor, Maine, which he has very carefully explored. Lobsters 3½ to 4 inches long were found quite often under rocks, where at *extreme* low tide there would be an inch or two of water, but it was only in the rock piles, where the rocks were several tiers deep, that the smallest lobsters were found. The smallest which Mr. Spinney sent me were taken in Small Point Harbor, October 9 to 19, and measured 1·56 to 1·62 inches; they were all found deep among the rock piles, where no enemy could reach them, and were about four months old. When the lobsters attain a length of 3 to 4 inches they leave the stone piles and take refuge under rocks, where they dig a small hole, in which they lie concealed when an enemy approaches.

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*See the paper by Dr. Loeb in this volume, pp. 65 to 68.

Yearling lobsters attain a length of at least 2 and possibly as great as 3 inches. The increase in length of individual larvæ at each molt is subject to considerable variation, as we should expect, but the average increase is strikingly similar to that seen in the adults. In either case the average increase in length at molting is from 12 to 13 per cent.

Placing the length of the lobster one year old at 2 inches, and knowing the average length of the larva at the time of hatching to be about one-third of an inch, or more accurately 8·5 mm., we can estimate the number of the molts the young must pass through during the first year of its life. Calculated on the basis of an increase at each molt of 13 per cent, the lobster, when it is 2 inches long must have molted sixteen times, and a 10½-inch lobster would have molted thirty times. This estimate is undoubtedly too great. It is, however, certain that during the first four months of its life the young lobster molts at least ten times. Beyond this period, I have not followed individual larvæ.

After reaching sexual maturity the female lobster does not, as a rule, molt oftener than once in two years. This is shown to be the case by the following facts. New-egg lobsters, taken in summer, are almost invariably hard-shelled, and since the majority of all lobsters molt in July, August, and September, the last shedding of such lobsters must have taken place ten months or a year before the time of egg extrusion. Furthermore, the eggs are carried for a period of at least ten months, during which, molting is out of the question. After the young are hatched, however, a molt follows in the course of a few weeks. When the ovary of a female which has hatched her young is examined, it is seen that the growing ova are in a very immature condition, and if their growth is studied at different times of the year it will be evident that they can not be extruded until the summer following the hatching of the last brood. We may therefore conclude that the sexual female lobster lays eggs and molts at intervals of two years, and that these biennial periods are one year apart.

I have known of only four or five cases of lobsters which have molted just before spawning. New egg lobsters with soft shells are, in fact, so rare that many intelligent lobstermen who have fished for a quarter of a century have never seen one.

As the lobster increases in age the molting period is undoubtedly lengthened, but it still takes place in individuals of extraordinary size, when one might suppose that the time of senescence had arrived.

The artificial propagation of the lobster is attended by difficulties which are not met with in dealing with the same problem in fish. The ripe eggs can not be pressed from the body and artificially fertilized and reared. They must be taken in a fertile and growing condition, when attached to the outside of the body of the female. The best incubator for her eggs is undoubtedly the lobster, and it would be better policy to leave matters with her, if she could be trusted in the hands of her greatest enemy, man. Unfortunately this is not the case, and a wanton destruction of lobsters "in berry" has taken place for many years. The eggs are illegally scraped off with a mitten or with the fingers, and thus allowed to perish by the millions, in order to send a few more lobsters to market.

The only ways open to secure an increase of the species are to protect the spawn lobsters, or to protect the immature until they have a chance to reproduce, or to take the eggs and rear them artificially. I will speak only of the latter expedient.

We have seen that the eggs are carried and carefully protected by the female for the space of ten or eleven months, and that the young receive no protection or fosterage from either parent, but swim near the surface, where they drift helplessly about, subject to indiscriminate destruction from storms and other causes. To maintain the species nature has made use of the common resource of producing a vastly greater number of young than can possibly survive under natural conditions. In order to keep the species at an equilibrium it would be only necessary for each pair to produce in the natural term of their life two adults to take the place of the parents. Since sexual females of the average size of 10½ inches produce 11,000 eggs at each reproductive period, there must be, in nature, a destruction of nearly the entire product. The survival of 2 in 10,000 would probably more than maintain the species at an equilibrium, and as the animal is markedly on the decrease the actual survival must be less than this.

It should be borne in mind that the number of eggs produced by lobsters exceeding 10½ inches in length increases very rapidly in proportion to the increase in length, according to the law already stated. A lobster 12½ inches long produces upwards of 20,000 eggs and a lobster 16 inches in length four times this number.

The length of 10½ inches is taken as about the average length of reproductive females at the beginning of their sexual maturity. The average length of mature females is undoubtedly much greater than this. Furthermore, every female which has reached sexual maturity reproduces once in two years. A large number, however, are destroyed before they have succeeded in rearing a single brood.

Taking these facts into consideration, and also the fact that the species as a whole does not appear to be maintained at present at an equilibrium, but rather to be actually on the decline, a little reflection will convince anyone that the destruction of the young of this species in nature must be much greater than that entailed by the survival of 2 in 10,000. Whatever survival there is under nature is a result of all the conditions of the environment, whether adverse or favorable, so that as long as the existing conditions remain the same, such as the persistency with which the fishery is conducted, the temperature changes, and those conditions which affect the supply of food, we may be sure that it is only necessary for each female in the course of her term of life, be it long or short, to bring two young ones to maturity in order to maintain the species at a uniform level.

We can readily see how even a slightly greater survival than this would be rapidly felt. Thus, let us suppose that there are at the present moment 50,000,000 lobsters in the waters of the Atlantic Ocean off the eastern coast of North America, and that the sexes are evenly divided. If each pair were to produce a pair to take their places, as the result of their sexual activity, or what is the same thing, if each female should produce two sexual individuals, there would be neither increase nor falling off in numbers. If every female were to produce three instead of two to take their places, the total number of individuals would be increased to 75,000,000, and if four were the product of each pair, the original number of lobsters would be doubled. If a similar increase were to take place in the human species famine and starvation would undoubtedly follow in many places, but so far as abundance of food is concerned it is certain that the lobsters could maintain themselves in far greater numbers than at present.

Reproduction is an expensive process, and the birth-rate among animals is therefore kept down to a minimum, which will provide against extinction by discriminate and indiscriminate causes. A high birth-rate is bad for the individual, but is good for the race, and is only resorted to when the chance of survival becomes very small. When the parents foster and protect the young, as is the case with birds and mammals, a very low birth-rate will suffice to maintain the species, but when these conditions are not present and the chances of reaching maturity are less and less assured, the birth-rate has in many animals been more and more increased, until in extreme cases the number of eggs produced amounts to tens or hundreds of millions.

The number of eggs or young produced by an animal is thus directly related to the habits of the animal in its early and adult stages. This is well shown within the group of the crustacea by a comparison of the common edible blue crab (*Callinectes hastatus*), or the lobster, with a deep-sea shrimp (*Parapasiphaë sulcatifrons*). The shrimp lays from 15 to 19 eggs, each one of which, according to Prof. S. I. Smith, measures 4·2 mm. (about one-sixth of an inch) in diameter, and is "approximately equal to a hundredth of the bulk of the animal producing it—a case in which the egg is relatively nearly as large as in many birds." The blue crab is said to lay 4,500,000 eggs, each of which measures only 0·28 mm. in diameter. We must infer that this shrimp has a short larval period; probably it hatches from the egg with all the external characters and habits of the adults. The blue crabs, on the other hand, or the young lobsters, leave the egg as immature forms, or larvæ, and have a number of weeks of free-swimming life, during which time they are subject to innumerable chances of destruction.

In the tapeworm we have an example of an animal which produces an extraordinary number of eggs, possibly reaching to tens or hundreds of millions. In some species the body is composed of as many as 3,000 segments, each of which is really an hermaphrodite individual which produces thousands of eggs. In order that any of this vast progeny may come to maturity, the eggs or embryos must be eaten by an herbivorous or carnivorous animal, and the flesh of this animal containing the encysted parasite must be eaten by still a second animal of a particular species, which forms the second host. It is thus evident that if the number of these eggs were few there would probably be no survival at all.

The production of a large number of embryos invariably means destruction to all but a very few, and if, in our attempts at artificial propagation, we place the young on the same footing which they would acquire in the ordinary course of nature, we can not expect that nature will treat them with any partiality.

The hatching and immediate liberation of the young of the lobster can be easily accomplished by the methods now in use, but it is clear that in order to sensibly affect the total supply, such a method must be conducted upon a very large scale. Allowing the survival of 2 individuals out of every 10,000 hatched, we would have to hatch 1,000,000 eggs to produce 200 adults, and 1,000,000,000 to produce 200,000. Since hundreds of thousands of lobsters are captured every month during the best part of the fishing season, it is evident that the annual supply can not be appreciably affected by this method when conducted upon its present scale.

If there were a loss of half or more of the product of eggs during the ten or eleven months while they are carried by the female, then we should increase the supply if we were able to take the eggs at an early day and secure the hatching of the entire number. As a matter of fact, however, unless the lobster is destroyed outright, she manages to preserve her eggs with remarkable success, and a very large proportion of the number originally laid are almost invariably hatched. In the case of many fish, on the contrary, which extrude their eggs into the water and leave them a prey to the elements and to enemies of all kinds, it will obviously tend to increase the species if we take the eggs, artificially fertilize them, and tide them over this early danger-period, as is now commonly done.

It is something to make one blade of grass grow where none has grown before, and it is well to use every means in adding, in however small a degree, to the supply of lobsters on our coast, but what I wish to point out is that we may deceive ourselves in regard to the success of our efforts. The placing of free-swimming crustacean larvæ in the ocean is a very different thing from placing young fish in a pond or stream, since the lobster, while restricted in its adult state, in its larval stage is at the mercy of the winds and currents and surface-feeding animals, and subject to distribution over very wide areas. This arises from the fact that while in this condition it lives near the surface of the water.

If we could save 100 instead of 2 out of every 10,000 hatched, every million young would give us 10,000 adults, and every billion would yield 10,000,000 lobsters, capable of reproduction. If we could preserve 1,000 out of every 10,000 eggs hatched (which is, of course, far too much to expect), every million young would yield 100,000 adults.

In view of these facts, it seems to me that, before liberating the young lobsters, an attempt should be made to rear them until they have passed their free-swimming stages, that is to say, until they have molted five times, and are from three to six weeks old. One hundred lobsters in the fifth or sixth larval stage would be of more value than many thousands of the youngest forms, since, like the adults, they then live upon the bottom and are able, in a great measure, to protect themselves.

Whether such an attempt would be successful or not, could be decided only after very careful experiments. Some of the conditions necessary for success can be outlined now, such as (1) the need of relatively large inclosures, where overcrowding, which inevitably results in destruction to the young, can be avoided; (2) a supply of pure sea water, as free from sediment as possible; (3) a means of regulating the light admitted to the inclosures (possibly a needless precaution); (4) a means of retaining the young without injury, so they will not have access to the water outside until the proper time.

The first step to be taken is to study the habits of the young in ponds, or places where they can be watched during the day and night, and to ascertain how near the surface they maintain themselves at such times.

While we can not say with certainty that, in the present state of our knowledge, such experiments would suceed, I believe that enough is known to encourage us to make an attempt in this direction.

13.—THE ORIGIN OF THE FOOD OF MARINE ANIMALS.

BY W. K. BROOKS,
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In a picture of the land, the mind calls up a vast expanse of verdure, broken only by water, and stretching through forest and meadow from high up on the mountains, over hills and valleys and plains, down to the sea.

Our picture of the ocean is an empty waste, stretching on and on, with no break in the monotony except, at long intervals, a floating tuft of sargassum or a flying-fish or a wandering sea bird, and we never think of the ocean as the home of vegetable life. It contains plant-like animals, "zoöphytes," in abundance, but while they resemble plants or flowers in form and color and in their mode of growth, they are true animals and not plants.

At Nassau, in the Bahama Islands, the visitor is taken in a small boat, with windows of plate glass set in the bottom, to visit the "sea gardens" at the inner end of a channel through which the pure water from the open sea flows between two coral islands into the lagoon. Here the true reef corals grow in quiet water where they may be visited and examined.

The bottom of the boat is below the surface ripples and reflections. When illuminated by the vertical sun of the tropics and by the light which is reflected back from the white bottom the pure, transparent ocean water is as clear as air, and the smallest object, 40 or 50 feet down, is seen distinctly.

As the boat glides over the great mushroom-shaped coral domes which arch up from the depths, the dark grottoes between them and the caves under their overhanging tops are lighted up by the sun far down among the flower animals or anthozoa and the animal plants or zoöphytes, which are seen through the waving thickets of brown and purple sea fans and sea feathers as they toss before the swell from the ocean.

There are miles of these "sea gardens" in the lagoons of the Bahamas, and it has been my good fortune to spend many months studying their wonders; but no description can convey any conception of their beauty and luxuriance, and I never spent a day among the reefs without longing, at every turn, for the skill to copy with a brush the new beauties which never ceased to present themselves.

The general effect is very garden-like, and the beautiful fishes of black and golden yellow and iridescent cobalt blue hover like birds among the thickets of yellow and lilac gorgonias. The parrot fishes (*Diodon* and *Ballistes*) seem to be cropping the plants like rabbits, but more careful examination shows that they are biting off the tips of the gorgonias and branching madrepores or hunting for the small crustacea which hide in the thicket, and that all the apparent plants are really animals. The delicate star-like flowers are the vermilion heads of boring annelids or the scarlet tentacles of actinias, and the thicket is made up of pale lavender bushes of branching madrepores and green and yellow and olive masses of brain coral, of alcyonarians of all shades of yellow and lilac and purple and red, and of red and brown and black sponges. Even the lichens which incrust the rocks are hydroid corals, and the whole sea garden is a dense jungle of animals where plant life is represented only by a few calcareous algæ so strange in shape and texture that they are much less plant-like than the true animals.

The scarcity of vegetation becomes still more noticeable when we study the ocean as a whole.

On land herbivorous animals are always much more abundant and prolific than the carnivora, as they must be to keep up the supply of food. Insectivorous birds are very abundant, but they are not numerous enough to keep the plant-eating mollusks and insects in check, and the devastation which is caused every year by the armies of grasshoppers and locusts and herbivorous beetles and by other less conspicuous insects shows that their natural enemies are not numerous enough to overtax their productive power.

The birds which feed upon grain and seeds and fruits are very abundant indeed, and they sometimes gather at their breeding-grounds or places of assembly in innumerable multitudes, but the hawks and owls which prey upon them are not very numerous.

The small rodents, such as the rats, mice, squirrels, and rabbits are the most abundant and prolific of animals; but the small carnivora are so rare that their very existence is known to few except naturalists and trappers.

The homes of the wild sheep and goats, deer, antelopes, cattle, and horses support these large mammalia in incredible numbers, but their carnivorous enemies are never abundant. It is clear that if the destruction of the plant-eaters exceeded their productive power, both herbivora and carnivora would disappear and terrestrial life would come to an end.

The animal life of the ocean shows a most remarkable difference, for marine animals are almost exclusively carnivorous.

The birds which live upon the ocean (the terns, gulls, petrels, divers, cormorants, tropic birds, and albatrosses) are very numerous indeed, so numerous that in many parts of the ocean some are always visible in calm weather around the vessel whereever it may be. The only parallel to the pigeon roosts and rookeries of the land is found in the dense clouds of sea birds around their breeding-places; but these sea birds are all carnivorous: most of them are fishers, and others, such as the petrels, scoop up the copepods and pteropods from the surface. Even the birds of the sea-shore subsist almost exclusively upon animals, such as mollusks, crustacea, and annelids.

The seals pursue and destroy fishes; the sea-elephants and walruses live upon lamellibranchs; the whales, dolphins, and porpoises and the marine reptiles all feed upon animals, and most of them are fierce beasts of prey. The manatee is a vegetable feeder, but it is not strictly a marine animal, since its home is in the mouths of great rivers.

There are a few fishes which pasture in the fringe of seaweed which grows in the littoral zone of the ocean, and there are some which browse among the floating tufts of algæ upon its surface, but most of them frequent these places in search of the small animals which live among the plants. All the floating fishes whose home is the floating sargassum—the file-fishes and trigger-fishes (*Ballistida*), the trunk-fishes (*Ostracion*), the frog-fishes (*Antennarius*), and the puffing-fishes (*Tetradon* and *Diodon*)—are carnivorous, living upon the barnacles and mollusks and hydroids which grow upon the sargassum, or upon the crustacea, young fishes, and the floating larvæ which seek its shelter.

In the Chesapeake Bay the sheepshead (*Archosargus probatocephalus*) browses among the algæ upon the submerged rocks and piles like a marine sheep, but its food is exclusively animal, and I have lain upon the edge of a wharf watching it crush the barnacles and young oysters until the juices of their bodies streamed out of the angles of its mouth and gathered a host of small fishes to snatch the fragments as they drifted away with the tide.

Many important fishes, like the cod, pasture on the bottom, but their pasturage consists of mollusks and annelids and crustacea, instead of plants.

The vast majority of marine fishes are fierce hunters, pursuing and destroying smaller fishes, and often exhibiting an insatiable love of slaughter, as in the case of our own bluefish and the tropical albacore and barracuda. Others, such as the herring, feed upon smaller fishes and the pelagic pteropods and copepods; and others, like the shad, upon the minute organisms of the ocean, but all, with few exceptions, are carnivorous.

In the other great groups of marine animals we find some scavengers, some which feed upon microörganisms, and others which hunt and destroy each other; but there is no group of marine animals which corresponds to the herbivora and rodents and plant-eating birds and insects of the land. The pelagic copepods are, of all the marine metazoa, the ones whose place in the economy of nature is most like that of the terrestrial plant-eaters. They swarm in innumerable multitudes at the surface of the ocean, and also below it down to a depth of a mile or more, and they furnish the chief food for most young fishes, and for great armies of herrings and pteropods and jelly-fishes and siphonophores, and for most pelagic larvæ.

There are plant-eating mollusks and echinoderms and annelids in the ocean, but not in sufficient numbers to play any conspicuous part in its economy, and the copepods are the only plant-eaters which exist in sufficient numbers to be compared with those of the land, and the food of the copepods is only partially vegetable, for they devour microscopic animals as well as microscopic plants, and probably to an equal amount.

The group crustacea as a whole is a carnivorous one, however, for while a few subsist on algæ, their number is inconsiderable. Others chew the mud of the bottom and extract its organic matter, but this is chiefly animal and consists of foraminifera and rhizopods and infusoria.

The mollusks as a whole are carnivorous, and while there are many exceptions, such as the nudibranchs, for example, many nudibranchs feed on hydroids.

The cephalopods and pteropods and heteropods and many of the gasteropods pursue and destroy their prey, and other gasteropods are scavengers, while the lamellibranchs gather up the microscopic organisms which are drawn into their gills with the water.

The majority of the worms and echinoderms are animal-feeders. Some of them, like the common starfish, are actively predaceous; others, like the crinoids, gather up microscopic organisms from the water; others, such as most holothurians, eat the mud of the bottom and digest out of it the foraminifera and small mollusks and annelids and crustacea which it contains, while others, such as the sea-urchins of the coral reefs, grind away and swallow the living coral. The universal presence of a poisoning apparatus in the cœlenterates shows that the food of this great and important group of marine animals must consist, in the main, of animals which are able to resist or to escape, and observation shows that this is true. Floating jelly-fishes and siphonophores are often found fastened to the half-digested carcasses of sagittas or heteropods or fishes larger than their captors, and they consume enormous numbers of copepods, pteropods, young fish, and pelagic larvæ of all sorts. So far as we know, all the sea-anemones and coral polyps and alcyonarians and hydroids are carnivorous. Some of the discomedusæ, the rhizostomes, feed upon microscopic organisms, but this mode of life is exceptional, and some recent observations, as yet unpublished, by Dr. R. P. Bigelow, show that the food of the rhizostomes consists of copepods.

Except for a few plant-eating fishes and mollusks and worms and echinoderms, all the animals of the ocean fall into two classes, those which subsist on microscopic organisms and those which prey upon each other and correspond to the rapacious animals of the land.

There is practically nothing in the ocean corresponding to the terrestrial herbivora, and nothing like terrestrial vegetation, except the fringe of seaweeds in the shallow water along the coast, and a few floating islands of algæ like the Sargasso Sea. While these tracts of vegetation are pretty extensive, they are totally inadequate to support the animal life of the ocean, and as the whole animal world is dependent directly or indirectly upon plants, we must ask what takes the place of terrestrial vegetation?

There is so much room in the vast spaces of the ocean, and the part which is open to our direct observation is such an inconsiderable part of the whole, that it is only when great multitudes of pelagic animals are gathered together at the surface that the abundance of marine life becomes visible and impressive; but some faint conception of the boundless wealth of the ocean may be gained by observing the quickness with which marine animals become crowded at the surface in favorable weather.

On a cruise of more than two weeks from Cape Hatteras to the Bahama Islands I was surrounded continually, night and day, by a vast army of dark-brown jellyfishes (*Linerges mercutia*), whose dark color made them very conspicuous in the clear water. They were not densely crowded, although they were so abundant that nearly every bucketful of water we dipped up contained some of them. We could see them at a distance from the vessel, and at noon, when the sun was overhead, we could look down into the water to a great depth through a well in the middle of the vessel where the centerboard hung, and as far down as the eye could penetrate, 50 or 60 feet at least, we could see the brown spots drifting by like motes in the sunbeam. We cruised through them for more than 500 miles, and we tacked back and forth over a breadth of almost a hundred miles, and they were everywhere in equal abundance.

The fishes in a school of mackerel are as numerous as the birds in a flight of wild pigeons. Goode, in his History of Aquatic Animals, tells of one school of mackerel which was estimated to contain a million barrels, and of another which was a windrow of fish half a mile wide and at least 20 miles long; but while the pigeons are plant-eaters, the mackerel are rapacious hunters, pursuing and devouring the herrings, as well as the pteropods and pelagic crustacea.

Herring swarm like locusts, and a herring bank is almost a solid wall. In 1879 300,000 river herring were landed by a single haul of the seine in Albemarle Sound; but the herrings are also carnivorous, each one consuming myriads of copepods every day. In spite of this destruction and the ravages of armies of medusæ and siphonophores and pteropods, the fertility of the copepods is so great that they are abundant in all parts of the ocean, and they are met with in numbers which exceed our powers of comprehension.

On one occasion the *Challenger* steamed for two days through a dense cloud formed of a single species, and they are found in all latitudes from the Arctic regions to the equator, in masses which discolor the water for miles. We know, too, that they are not restricted to the surface, and that the banks of copepods are sometimes a mile thick. When we reflect that thousands would find ample room and food in a pint of water, we can form some faint conception of their universal abundance.

As the result of our view, we find that the organisms which are visible without a microscope in the water of the ocean and on the sea bottom are almost universally engaged in devouring each other, and many of them, like the bluefish and the albacore, are never satisfied with slaughter, but kill for mere sport.

Insatiable rapacity must end in extermination unless there is some unfailing supply, and as we find no visible supply in the water of the ocean we must seek it with a microscope. By its aid we find a wonderfully rich and diversified fauna made up of innumerable larvæ of all sorts of marine animals, together with a few minute and simple metazoa, but these things can not form the food supply of the ocean. It is clear that a single carnivorous animal could not exist very long by devouring its own children, and the result must be the same, however great the number of individuals or species.

The total amount of these organisms is inconsiderable, however, when compared with the abundance of a few forms of protozoa and protophytes, and both observation and deduction force us to recognize that the most important element in the total amount of marine life consists of some half a dozen types of protozoa and unicellular plants, of globigerinæ and radiolarians, and of trichodesmium, pyrocystis, protococcus, and the coccospheres, rhabdospheres, and diatoms.

Modern microscopic research has shown that these simple plants, and the globigerinæ and radiolarians which feed upon them, are so abundant and prolific that they meet all demands and supply the food for all the animals of the ocean. This is the fundamental conception of marine biology. The basis of all the life in the modern ocean is to be sought in the microörganisms of the surface.

This is not all. The simplicity and abundance of the microscopic forms and their importance in the economy of nature show that the organic world has gradually shaped itself around and has been controlled by them. They are not only the fundamental food supply, but the primeval supply, which has determined the whole course of the evolution of marine life.

The pelagic plant-life of the ocean has retained its primitive simplicity on account of the very favorable character of its environment, and the higher rank of the littoral vegetation and that of the land is the result of hardship.

On the land the mineral elements of plant-food are slowly supplied as the rains dissolve them; limited space brings crowding and competition for this scanty supply; growth is arrested for a great part of each year by drought or cold; the diversity of the earth's surface demands diversity of structure and habit, and the great size and complicated structure of terrestrial plants are adaptations to these conditions of hardship.

The conditions of the surface of the ocean; the abundance and uniform distribution of mineral food in solution; the area which is available for plants; the volume of sunlight and the uniformity of the temperature, are all favorable to the growth of plants, and as each plant is bathed on all sides by a nutritive fluid, it is advantageous for the new plant cells, which are formed by cell multiplication, to separate from each other as soon as possible in order to expose the whole of their surface to the water. Cell aggregation, the first step towards higher evolution, is therefore disadvantageous to the pelagic plants, and as the environment is so homogeneous at the surface of the ocean that there is little opportunity for an aggregation of cells to gain a compensating advantage by seizing upon a more favorable habitat, the pelagic plants have retained their primitive simplicity.

The list of pelagic microörganisms is a long one, but a few forms are so predominant that the others have little significance at the present day in comparison, and we may regard the great primary food-supply as made up of two simple protozoa, globigerina and the radiolarians, and some five or six unicellular plants.

Of these only two, the radiolarians and the diatoms, show any great diversity of species; and while the radiolarians are so diversified that the *Challenger* collection alone furnished more than 4,000 species, this variety does not obscure the primitive simplicity of the type, and the most distinctive peculiarity of the microscopic food supply of the ocean is the very small number of the forms which go to make up the enormous mass of individuals.

14.—ATMOSPHERIC AND OTHER INFLUENCES ON THE MIGRATION OF FISHES.

BY J. J. ARMISTEAD,

Solway Fishery, Dumfries, Scotland.

The subject now before us is one that plays a highly important part in the economic history of our food-fishes. During the last ten or fifteen years the migrations of birds have been extensively worked out by experts, and much light thrown upon the movements of these creatures. To put the matter in a practical way, what we want is a somewhat similar arrangement of forces, by which the migrations of fishes can be taken note of by any one who in any way comes in contact with them, and who is sufficiently interested, or can be sufficiently interested, in their existence to record the smallest facts concerning their movements and send in these records to some central station, where they may be made good use of and the results made known to science. The case in the matter of fishes is not so easy perhaps as in the case of birds, and yet what could be simpler than for a fisherman on some particular date to record such a series of facts as the following:

May 29, 1893; first large run of salmon, on flood tide, 17 feet 10 inches; wind light, WSW., showery.

On being received at headquarters probably other similar reports would arrive from various stations in the same district, and in case of any rivers not reporting, application should be made for information. In this way much valuable information might be collected, condensed, and published. Although an individual observer can do comparatively little, yet a number working together might do a great deal.

I have endeavored, as opportunity has offered, to make a few observations which I have recorded from time to time, and refer to them now in the hope that others may be interested and stimulated to similar effort. The more we work out the facts about the migration of fishes, the more complex very often does the question appear to become.

Primarily, there are two causes which lead to migration, (1) food supply and (2) reproduction of species. It has frequently been asserted that salmon do not feed, but every one who is acquainted with the life-history of that fish (*Salmo salar*) is well aware that they not only feed, but feed voraciously. It is not necessary to go to a fish-culturist to make sure of that fact. Salmon have been kept in fresh water from the time of their birth to maturity, and after the absorption of the umbilical sac have fed and continued to feed very much in the same way that other members of the family are known to do.

Every trout-angler who has fished in a salmon river knows how readily the yearling salmon or "parr" will take a bait. The fish at this stage has on its sides the "bars" or "finger marks," as they are often called, and bears a great resemblance to a trout, but presently puts on the livery of the smolt and goes to sea. This change means that it loses the peculiar "finger marks" on its sides, and also the general trout-like appearance, and becomes very silvery. It was formerly supposed that this silvery appearance was caused by a fresh growth of scales, but that has been found not to be the case. It is caused by a silvery pigment on the under sides of the scales, and on the opercles, which are scaleless.

Some years ago a rather interesting experiment was tried. A number of salmon parr were taken from the river and placed in an aquarium tank. In due course about half of them developed into the smolt stage. The others did not. Sea water was then turned on, the supply of fresh water having been previously cut off, and the water in the tank was gradually changed from fresh to salt. What was the consequence? Some people affirm that "parr" will not live as such in salt water. These not only lived, but very rapidly assumed the smolt stage after the salt water was added.

Now, we know that parrs feed. Anglers know, as I have already said, that they will take almost any bait. They have been found gorged with shellfish, crustaceans, and the larvæ of aquatic insects, etc. "Smolts" also feed voraciously; indeed, I have known them completely spoil the sport in a river.

Can it be supposed that the salmon in its early stages, during which it does not make any abnormally excessive growth, feeds voraciously, and after going to the sea takes either no food or very little, notwithstanding that the smolt, which has left the river perhaps less than a quarter of a pound in weight, returns in a few months as a grilse weighing 6 or 7 pounds. It seems unreasonable. It is found amongst domesticated fish, and this applies to the salmon, that at certain times of the year they feed very freely and at other times they take very little, but at all times more or less food is taken.

At Stormontfield on the Tay it was noticed on one occasion that the smolts which were to be let down to the sea were of a very much larger size than they had been in previous years. It was found on inquiry that the ponds had become charged with minute shellfish, and the liberal diet these afforded accounted for the extra growth of the smolts. Some smolts return from the sea as grilse in two or three months; others in fourteen or fifteen months. Those which return in three months have, taking a very low estimate, attained a weight of some 3 pounds; whereas those which have remained in the sea for the longer period, say from May of one year to July of the following year, do not attain a very much greater size than those which return in the shorter period. Exactly the same peculiarity has been noticed in the case of tame trout kept in ponds. Some grow very much more rapidly than others, and the period of a pondful of trout arriving at maturity will often vary a year and sometimes even two years.

It has been found, in some instances at least, that "parrs" become "smolts" and go to sea, some of them the first year; the great majority the second year; and some not till the third year. This, too, is found to be very much the case amongst domesticated trout. It is found necessary at the end of the first year to take them out of the pond and sort them. If this be not done the larger fish will eat many of the smaller ones, and at the end of two or three years their sizes would be altogether disproportioned, some weighing only 2 or 3 ounces, others as many pounds. I have known cases of trout (*S. fario* and *S. levenensis*) reaching the weight of 4 pounds in two years, whereas it usually takes three years for a trout to reach a pound.

A smolt weighing a few ounces let off at Stormontfield on the Tay in the month of May returned in July of the same year weighing 3 pounds. On the other hand, a smolt which His Grace the Duke of Roxburghe let off on May 14 did not return until July of the year following, and it had then attained a weight of only 6½ pounds, having, in fourteen months, only just doubled the weight gained by the other fish in less than three months.

These and many other observations tend to prove that fish spending a long time in the sea do not continue to grow at the same rate as during the first few months. There is little doubt but food supply is the great incentive which drives salmon to the sea. They feed, and feed voraciously, in our rivers at times. But sometimes they take but little food—as, for instance, when spawning, when the temperature is very low, and when on migration. It is quite possible, for these reasons, to get plenty of salmon with nothing in their stomachs; and, as their digestion is very rapid, even after a good meal little trace of it might be found in a few hours.

The idea seems to exist in many minds that the huge bodies of the salmon are developed by a very indefinite something which the fish manage somehow or other to obtain by a process which they call suction; and this, as a recent writer very aptly remarked, points to something rather like microscopic supplies.

There is, however, no doubt that the food of the salmon, when in the sea, consists largely of herrings, young and old, sand eels, crustacea, etc. They follow the young herrings in shoals closely, and in many cases are found gorged with these fish. So much is this the case that when, a few years ago, the herrings failed to visit a part of the Scotch coast at the accustomed time, the salmon also failed to turn up in anything approaching their usual numbers; indeed, hardly any salmon were to be got at all, although they were usually very plentiful during the herring season. In the summer there are a good many young herrings in the Solway Firth, as I have frequently found when dredging, etc. It is a curious fact that the herring, which formerly was excessively abundant as a mature fish in the Solway, should have left it entirely, although immense quantities are still found in the sea just outside the Firth.

A great many reasons have been given for the desertion of the Solway by the herring. It took place about thirty years ago, and people blamed steamboats, trawling, railways, and many other things, but no really satisfactory reason could be given, and I am not aware that anyone has ever yet explained the mystery. But knowing as we do now what a great influence temperature has on the movements of fishes, and putting other facts together, I dare say if we could put the question to the herrings and get an answer from them it would be that we had rendered the water of our Firth unsuitable, and therefore they prefer keeping out of it. About the time the fish left, or just before it, there was a great rage for hill drainage, and the result of this hill drainage was that an amount of rainfall that formerly took several weeks to run off came down in about three days, during which time the rivers draining the watershed were in a state of high flood. Now when we take into consideration that the watershed of the Solway Firth is about ten times as big as the Solway itself, it will be seen that the effect of this hill drainage on the water of the Firth must be very great, especially taking into account the shallowness of the estuary in question. The same has been noticed elsewhere where conditions are somewhat similar. But in some of our deeper lochs, where the water would not be affected so easily, the herrings still remain.

The migration of the herring is not to and from the Arctic regions, as was once supposed and as was reported by all the older naturalists, but simply from deep to shallow water, and I am convinced that they really remain comparatively near our islands all the time. Their migration, it has been found, depends largely on temperature. The study of the movements of these fishes is a very interesting one, and well worthy of a considerable amount of time, labor, and money being spent on it. No one who has not seen a herring shoal can form a conception of what it is like or of the enormous numbers of fish it contains. If we allow a herring for every cubic foot and assume a shoal to be a square mile in extent and 18 feet deep, it would contain 500,000,000 of fish; and there are a great many shoals of vastly larger dimensions. Such, indeed, is the enormous rate of increase that the whole quantity caught by man does not appreciably affect their numbers, and they would literally choke up the sea if they were not largely destroyed by other fishes as well as by birds. One of the fishes most destructive to the herring is the cod, which follows the shoals as well as the salmon, to which I have already referred.

The return of this latter fish to the rivers is an exceedingly important economic question. During autumn, when they run up the river to spawn, they take, perhaps, less food than at any other time, but the abundance amongst which they have been living previously has caused such a development of fat that the fish are really provided by nature to a great extent with the food which they require at this particular time. Very much the same has been observed with regard to domesticated fish. On a trout farm, for instance, it is observed that as soon as we reach October the fish which are in the habit of spawning at that time almost cease to feed, whereas the occupants of other ponds which do not spawn until January go on feeding until hard frost sets in and the water becomes very low in temperature.

Fish being cold-blooded animals pass into a more or less torpid condition during cold weather. The influence of an approaching thunder storm in preventing fish from rising is well known. Fish also often do not rise when the barometer is falling, whereas when we have a steady rise in the barometer from the west a good run of salmon is often noticed in the west coast rivers. But when the barometer reaches 29.50° the run ceases. It has also been observed that they run better in west coast rivers when the barometer is lower on the west coast than it is on the east coast. When it is rising and reaches 29° the best run occurs; and from 29.50° seems to be the most favorable point.

Temperature is also an important factor in connection with the migration of fishes of probably all kinds. It must generally happen that the temperature of a river differs from that of the sea or the estuary. Many writers have remarked that the low temperature of the sea induces the salmon to leave it and seek the higher temperature of our rivers. This has been particularly remarked about our North Sea and east coast rivers, which are earlier than those on the west coast. Fish-culture has taught us a good deal here. It was found that in cold weather fish were later in spawning than in mild weather; that during a hard frost they spawn very tardily; and when there is a mild rain and rapid thaw they spawn more freely than under any other

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circumstances. If an apparently ripe fish, from which it is found impossible to obtain ova, be taken from ice-cold water and placed in a tank, the inflowing stream of which is gradually raised from 32° to 50° Fahrenheit, it will be found under such conditions to yield its eggs freely.

Some time ago, when trying to obtain ripe salmon in the river Nith, I found it quite impossible, though a large number of the fish were taken. I found, however, that fish were spawning freely in the river Cluden, which is a fork of the Nith. I had thermometers placed in the two streams, and the result bore out the opinion I had previously formed, namely, that the water of the Cluden was warmer than that of the Nith.

On a stream of my own I have noticed repeatedly that during a mild spawning season trout avoid one of the tributaries. The reason is that the temperature of this tributary is so much lower than that of the main stream. It is very little affected by the weather, being mostly spring water. But let the weather be reversed and hard frost set in, the fish then take this tributary freely because the water is several degrees warmer. I have remarked other instances in which the same thing occurs.

It has been said that the temperature of the sea being colder than that of the rivers the fish leave it, seeking a higher temperature. I have not noticed this so much myself, but I have seen it mentioned as the experience of some writers, and have also seen it recorded in the Government fishery reports and elsewhere. But this I have noticed, that the temperature of the sea, in some places at least, during the late spring months is often a great deal higher than that of the rivers, very often varying 10° F. or more. It has often puzzled naturalists why salmon run up the rivers in spring and summer, and many reasons have been put forth, such as change of food, to get rid of parasites, to escape from seals, etc. But none of the reasons brought forward will bear much scrutiny.

The following, however, has occurred to me: Knowing how important it is on a trout farm so to feed and care for the fish in the spring as to build up the ova, which are then developing in the ovaries, and knowing that the proper or improper treatment of the fish at this time means a lot of good or bad ova the following season; knowing also what a great effect temperature has on the spawning of fish, one would infer that the high temperature of the sea water has such an effect on the reproductive organs that it may compel the fish to leave the warmer waters of the sea and take refuge in the rivers. These early fish, too, are the best fish, and very naturally so, clean-run fish as we call them.

When the water of the sea is of a low temperature, as in early spring, we do not get in our Solway rivers such a large run of fish as we get later on. In the month of March, for instance, when the east winds are blowing, the fish do not run nearly so well as in April, and they do not run so well in April as in May. From 1880 to 1884 I took up my residence at a place on the coast called Douglas Hall, where a considerable salmon fishery existed, there being four stake nets fishing over a dozen pockets or pounds. So regular was this spring run that, although the fishing legally commenced in February, the nets were not put on before the end of March, and some of them in April, because it was not remunerative to put them on earlier on account of the scarcity of salmon. But later on, as the sea became warmer, a good many fish were found running. If the weather remained cold and the temperature of the sea remained at a low point the fish did not run; but as soon as the state of things was reversed, no matter what the day of the month, in came the fish.

Among other things it seems to be a general impression that a heavy spate causes a good run of fish up a river. I believe that in many instances this is so, but I find that there are exceptions to this rule, and nature seems to have an unerring code of laws governing these migrations. Sometimes a heavy spate occurs without any fish running. I believe I am right in saying that the bulk of the salmon entering our rivers only run on spring tides, and on those tides preceding the highest spring more than the two or three tides after the highest spring. And if the inflow of the spring tide be accompanied by a strong westerly wind on our west coast rivers, more fish come up than if there be no wind at all; and should the wind happen to be from the eastward, a very much smaller number would come up. Now, what effect has the wind on the tide? A strong westerly wind causes the tide in our rivers to rise higher, to flow longer, and to remain high longer; and if the fish run, as they appear to do, on the top or head of the tide, as it were, a westerly wind, causing the tide to flow even half an hour longer, would give a chance for far more fish to get up than if it had stopped at the ordinary time.

It is supposed, generally, that salmon only run with the flood; that if they find the tide ebbing they turn back to the sea and run up with the next tide. The larger run of fish is therefore accounted for by the longer time they have to run. More fish come up from neap to spring than when the tides are falling off from spring to neap, and during that period of time the only tides upon which fish will run to any extent are those just after the highest spring. Should a land spate occur at the same time a very good run of fish may be looked for, especially if it be accompanied by a west or southwest wind. In many instances I am exceedingly sorry to say a land spate is almost a necessity in many of the rivers to enable the fish to get through the pollutions and over the numerous obstacles which they meet with in their ascent.

It has been said sometimes that fish can smell the rain, and certainly they often appear to know beforehand when it is coming. I have reason to believe that fish sometimes run into a river, anticipating a spate. So trout in a pond will sometimes become very restless, and run up the raceways and then, in an hour or two, down comes the rain. It is most important to get reports from streams which are in a state of nature, unpolluted and unmolested, as far as possible. Such is the stream which passes near my own hatchery, and on which I am a riparian owner. It is a small stream and only frequented by a few salmon; fewer, I believe, than in former years. During one spawning season I personally devoted a considerable amount of time to studying the habits of the salmon in this stream. I believe I made the acquaintance of every salmon that passed up that stream for about a month. As a rule, I found that they did not run by day, but by night. Only during a heavy spate would they run by day. During some nights they did not run at all, on other nights several went up. The early fish were nearly all males; indeed it was quite exceptional to get a female early in the season. Later on I found both sexes coming up. I found, also, that they almost invariably ran on spring tides, and that they did so whether there was a spate or not. A westerly gale during spring tides was followed, as I expected, by a good run of fish. I noticed one pair of fish particularly, that came towards the end of the season; they had evidently, from some cause, been prevented ascending the stream before. They went upstream until they came to a place that suited their ideas, and there they stopped and constructed a redd and deposited their ova. The operation took about a week. I then took away the female and confined her in a tank, and waited to see what the other fish would do. I thought it extremely probable he would go upstream and try to find another female. But instead of that he dropped down into the next pool further downstream, and remained there two days and two nights; on the third night he dropped down three pools further, then into another pool further downstream, and from there he journeyed seawards.

Fish having spawned evidently have a desire to get away to sea again, and I believe it is owing to their often not being able to get away with sufficient rapidity that they are attacked by the horrible fungous (*Saprolegnia*) disease which abounds in our rivers during some seasons.

One remarkable occurrence which I observed was the sudden appearance in the stream of four spent female fish, which, I was perfectly satisfied, had not been in the stream before. I concluded that they were fish from the main river, which had descended that river after spawning and, for some reason or other, took a run up this tributary for about three miles.

When observations of this kind are made on most of our streams, and reports sent in to some central committee, to be investigated and classified, as has already been done in the case of birds—when all those who are personally interested in our fisheries bestir themselves and investigate the facts in connection therewith, or place facilities in the way of others who can do it for them, then we can expect to unravel the mysteries of nature.

That salmon often return year after year, not only to the same stream, but to the same spawning bed, is a well-ascertained fact. The case has a striking parallel amongst birds, as, for instance, in that of the swallow. But there is a very large field for inquiry into these interesting matters; and I hope the foregoing remarks may be the means of stimulating others to the good work, which the scientist or the tyro will alike find productive of much enjoyment, whilst they will have the satisfaction of knowing that the result of their researches may be of much value to those who have to deal with our fisheries and the important questions concerning them.

15.—SOME OBSERVATIONS CONCERNING FISH-PARASITES.

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The purpose of this paper is twofold—first, to present, in the form of general considerations, some of the results of my own work; and, second, to suggest certain lines of research along which future investigations on fish entozoa should be made. In pursuance of this plan, bare anatomical details and wearying recapitulation of the names of helminthological writers and their works will be kept in the background.

I.

It is probably now pretty well known by most persons of average intelligence and information that cases of parasitism are not exceptional facts in nature, but that there is a fauna of considerable extent whose natural habitat is within other animals. Much work remains to be done before an approximately correct estimate can be made of the number of species which pass their lives within other animals. Von Linstow's *Compendium der Helminthologie*, 1878, enumerates 1,917 species of animals from which entozoa to the number of 2,755 distinct species have been reported. There are probably several duplicates in this list, but they are offset many times over by the new species which have been added to helminthological science in the fifteen years that have passed since the publication of Von Linstow's work.

There are few general statements in natural history that do not require qualification; and the one which would say when one animal eats another the life of the latter is by that act terminated affords no exception to the general rule. For, without doubt, there are thousands of species of animals which live to be eaten, and if eaten, live; and, conversely, if not eaten, perish. Those forms which take up their abode within other animals are, for convenience, called guests, and the animal which affords such entertainment to others is called the host.

Of all animals which nature thus requires to keep open house, the class of fishes takes the lead, not only for the variety of the forms and the number of the individuals harbored, but also for the frequency of individual cases of parasitism.

The cases of parasitism had in mind in the preparation of this paper all belong to those kinds which pass the entire cycle of their lives within other animals, that is, to the entozoa, properly so called.

II.

Each distinct species of fish is not unusually the host of one or more distinct species of parasite, or, at least, the usual host of one or more species. This is true especially of those species which belong to rather small natural orders, and which stand stiffly apart from other species. It will not, I think, be found so true of species, so-called, which are based on trivial differences. Therefore, when one is examining an animal for parasites from which no parasites have ever been reported, the probability is that if he finds any they will be new to science, especially if no parasites have been reported from any closely related species.

I will cite but one example, out of many that have come to my notice, in illustration of this conclusion. Some years ago I collected some entozoa from a specimen of *Polyodon spathula* from the Ohio River, a species from which, so far as I know, no entozoa had been reported, and which, moreover, is so different from any other existing species as to lead one to expect to find some entozoa or entozoon new to science. I found it harboring a considerable number of young cestodes belonging to the genus *Dibothrium*, which I shall describe and figure in a forthcoming report. Although the anatomy of the proglottides can be made out but imperfectly from my specimens, the external characters present such striking peculiarities that, even in the absence of many details of structure that are desirable to know in describing a new species, I feel justified in regarding it as a new species. I have found the same species in a lot of entozoa sent to me for identification by the U. S. National Museum. They are also immature, but there is not the slightest difficulty in establishing the identity of species in the two lots.

The above general statement is not to be understood to refer to larval forms, nor to mean that each species of entozoon is confined to a single host. Many of the nematodes, for example, and many of the cestodes, while in the encysted state, and a few in the adult, have a range of several hosts. I think it may be safely stated, however, that where two hosts are not nearly related the entozoa which infest one will, in general, be different from the entozoa which infest the other. On the other hand, hosts which are closely related are likely to be infested with similar entozoa.

For example, I have found repeatedly, in a number of species of flounders, viz, *Pseudopleuronectes americanus*, *Paralichthys dentatus*, and *Limanda ferruginea*, an echinorhynchus, often very abundant, which I have referred, somewhat questioningly, to the species *Echinorhynchus acus* Rud. Its favorite host is *P. americanus*, but it is far from uncommon in other flounders. Its range, however, does not appear to be limited to the *Pleuronectidæ*, for I have found specimens indistinguishable, except by a too refining process of species-making, from *E. acus* of the flounder, in the cod, haddock, sea-robin, sculpin and goosefish (*Gadus morrhua*, *Melanogrammus æglifinus*, *Prionotus evolans*, *Cottus æneus*, and *Lophius piscatorius*).

This parasite is easily recognized by its color. In a large lot of them, and they frequently occur to the number of a hundred or more in the same host, particularly in *Pseudopleuronectes americanus*, the colors will be found to graduate from deep orange through pale lemon-yellow to cream-white. When placed in the ordinary preserving or hardening fluids they are apt to contract strongly, but if placed in fresh water while still alive they become turgid and straight.

A dibothrium (*D. manubriforme* Lt.) which I found in the billfish (*Tetrapterus albidus*) was, in the subsequent summer, found to infest also the closely related species, the sailfish (*Histiophorus gladius*). This dibothrium, while it bears some resemblance to *D. plicatum* of the swordfish (*Xiphias gladius*), is specifically different from it.

A singular cestode (*Thysanocephalum crispum* Lt.), found in 1883 and again in 1889 in the tiger shark (*Galeocerdo maculatus*), is apparently peculiar to that species. Likewise another cestode, which I have found repeatedly from 1882 to 1889 in the land shark (*Carcharias littoralis*), and which I have described under the name *Crossobothrium laciniatum*, appears to be peculiar to that host.

In general I may say that in a majority of the species which I have examined from which no entozoa had been already reported, I have found one or more entozoa that proved to be new to science.

While it would, of course, be entirely improper to set up peculiarities of this kind as criteria for the determination of species, I venture to say that the helminthologist who finds two species of fish, which ichthyologists have made generically different, habitually harboring identical kinds of entozoa, under similar circumstances, would not be surprised to see these genera united by the next disturber of ichthyological nomenclature; and, conversely, if two species which systematists have regarded as being closely related should be found to harbor a completely diverse set of entozoa under similar conditions of migration, food supply, etc., sufficient reason would thereby be afforded for asking that the morphology of the two species in question be reviewed.

Certain natural groups of animals, as orders for example, are infested by certain genera or even families of entozoa which are peculiar to them.

A notable example of this is furnished by those remarkable cestodes which have four eversible spinose proboscides, belonging for the most part to the two genera *Rhynchobothrium* and *Tetrarhynchus* and forming the family *Tetrarhynchidæ*. The *Tetrarhynchidæ*, in their adult form, are confined to the *Elasmobranchii*, sharks and skates. For this limitation of their habitat other vertebrates can not be too thankful. The proboscides are often relatively long, abundantly long enough in most cases to penetrate the mucous and submucous coats of the alimentary canal of their host. They are armed with multitudes, often a thousand or more, of sharp, recurved hooks, so that when they penetrate the stomach or intestinal walls of their host they can be dislodged only with great difficulty. They often burrow a little pit in the intestinal wall, where sometimes a cluster of scolices will be lodged together. I have occasionally seen the stomach and intestine of a large shark with several ulcerated pits due to the presence of such parasites. As a rule, however, the presence of a moderate number of intestinal parasites in the adult stage does not apparently cause much discomfort to the host. The sharks, for example, which I have examined, and I have examined a goodly number, all appeared to enjoy excellent digestion; their accessory digestive organs being in nearly every case clean and bright. Indeed, if a parasite were to cause much mortality by its presence in its final host it would not be long, as things go in the economy of nature, until it would either cause the destruction of the species to which its host belongs, or at least makes it exceedingly rare, and thus imperil its own existence as a species. Hence, among the entozoa of fishes, as among those of man and the domestic animals, it is the immature stage of the parasite that causes most mischief, and it works that mischief not on the final but on the intermediate host.

III.

It will be worth our while now to consider some of the injurious effects of the presence of entozoa among fishes.

I have found the larvæ of many of the *Tetrarhynchidæ* encysted in a number of food-fishes of our coast, such as *Pomatomus*, *Cynoscion*, *Scomberomorus*, *Lobotes*, *Caranx*, *Gadus*, etc. These were invariably blastocysts, inclosed in cysts of connective tissue and each containing an embryo tetrarhynch more or less developed. They occur in the body cavity, where they are either attached to the serous covering of the viscera, peritoneum or mesentery, or they may be buried in the liver or spleen or lying between some of the coats of the stomach or intestine.

The scolex of a tetrarhynchus of the dusky shark (*Carcharinus obscurus*) is quite common in the squeteague or weakfish (*Cynoscion regalis*), where it may be found under the submucous coat of the stomach and intestine, often dotting the whole length of the alimentary tract with small specks. If one of these specks be punctured in July and August (the only months in which I have collected them) a small squarish or roundish scolex of a tetrarhynch is liberated. The abundance of these scolices in a single host explains the occasionally great abundance of the adult stage in the pyloric division of the stomach and the spiral valve of the dusky shark. That is, in such cases the shark has made a meal off of one or more fishes which were infested with the larval tetrarhynch in the encysted stage.

The cycle of life of these forms has not been proved in all cases, but from what is known of other members of the order it may be thus summarized: The larval tetrarynchs having been liberated by the action of the digestive fluids of the shark attach themselves to the walls of the stomach and intestine of this their final host, where they develop into the mature form, and whence chains of proglottides, containing numerous ova, escape. Some of these in due time may be themselves eaten by a squeteague or other fish, in which the ingested ova, instead of yielding to the action of the digestive fluids along with other food, undergo normal development, are hatched into minute six-spined embryos, which, boring through the tissues and finding lodgment somewhere in the body cavity of the intermediate host, there develop into a blastocyst in which a larval tetrarynch by and by makes its appearance. The larva, apparently, does not usually have the power of escaping from the blastocyst unless it is swallowed by the proper final host. These encysted forms in the squeteague, bluefish, etc., where only a few individuals are present, probably do little harm. It must be remembered, however, that the nourishing of every cyst is at the expense of a certain amount of vitality of the host; as the vitality of the host is diminished, the chances of its being caught by an active enemy are increased. Parasitism thus tends to perpetuate itself. The life-history of all these forms that require the intermediation of two hosts which stand toward each other in the relation of eater and eaten, has become adapted to the various vicissitudes and interrelations of the hosts.

Sometimes the presence of the parasite must work positive injury to its host. A case in point is that of a parasite which infests the liver of the large sunfish (*Mola rotunda*). I have been able to verify the statements of Cobbold concerning this parasite (*Tetrarhynchus repens*) and have seen the liver of a large mola tunneled in various directions by this parasite until the whole organ was little more than a sac of worms. Such a state of affairs must occasion a decided loss of vitality to the sunfish, and doubtless often causes it to fall a prey to some enemy from which it might otherwise easily escape, if the parasite does not at times itself bring about the death of its host.

One of the most interesting cases of parasitism in which direct injury results to the host, which has come to my attention, is that afforded by the trout of Yellowstone Lake (*Salmo mykiss*). It was noticed by successive parties who visited the lake in connection with government surveys that the trout with which the lake abounded were, to a large extent, infested with a parasitic worm, which is most commonly in the abdominal cavity, in cysts, but which in time escapes from the cyst and tunnels into the flesh of its host. Fish, when thus much afflicted, are found to be lacking in vitality, weak, and often positively emaciated.

It was my good fortune, in the summer of 1890, to visit this interesting region for the purpose of investigating the parasitism of the trout of Yellowstone Lake. The results of this special investigation were published in the Bulletin of the U. S. Fish Commission for 1889, vol. IX, pp. 337–358, under the title: "A contribution to the life-history of *Dibothrium cordiceps*, a parasite infesting the trout of Yellowstone Lake."

I found the same parasite in the trout of Heart Lake just across the great continental divide from Yellowstone Lake, but did not find any that had tunneled into the flesh of its host, while a considerable proportion of the trout taken in Yellowstone Lake had these worms in the flesh. Some of these worms were as much as 30 centimeters in length when first removed; others, which had lain in water a few hours after removal before they were measured, were much longer, as much as 54 centimeters. They are rather slender and of nearly uniform size throughout, 2.5 to 3 millimeters being an average breadth of the largest. I found the adult stage in the intestine of the large white pelican (*Pelecanus erythrorhynchus*), which is abundant on the lake and was found breeding on some small islands near the southern end of the lake.

In the paper alluded to above, I attempted to account for two things concerning this parasitism among the trout of Yellowstone Lake: First, the abundance of parasitized trout in the lake; second, the migration of the parasite into the muscular tissue of its host. The argument can not be well summarized in as short space as the requirements of this paper demand. It is sufficient to say that what appear to me to be satisfactory explanations are supplied by the peculiar conditions of distribution of fish in the lakes of this national park. Until three or four years ago, when the U. S. Fish Commission stocked some of the lakes and streams of the Park, the conditions with relation to fish life in the three principal lakes were as follows: Shoshone Lake, no fish of any kind; Heart Lake, at least three species, *Salmo mykiss*, *Leuciscus atrarius*, and *Catostomus ardens*; Yellowstone Lake, one species, *Salmo mykiss*. Shoshone and Yellowstone lakes are separated from the river systems which drain them by falls too high for fish to scale. Heart Lake has no such barrier. The trout of Yellowstone Lake are confined to the lake and to 18 miles of river above the falls. Whatever source of parasitism exists in the lake, therefore, must continue to affect the fish all their lives. They can not be going and coming from the lake, as the trout of Heart Lake may freely do. If their food should contain eggs of parasites, or if the waters in which they swim should contain eggs or embryos of parasites, they would be continually exposed to infection, with no chance for a vacation trip for recuperation. To quote from my report:

> It follows, therefore, from the peculiar conditions surrounding the trout of Yellowstone Lake, that if there is a cause of parasitism present in successive years the trout are more liable to become

infested than they would be in waters where they had a more varied range. Trout would become infested earlier and in greater relative numbers, and the life of the parasites themselves—that is, their residence as encysted worms—must be of longer duration than would be the rule where the natural conditions are less exceptional. * * * There are probably not less than one thousand pelicans on the lake the greater part of the time throughout the summer, of which at any time not less than 50 per cent are infested with the adult form of the parasite, and, since they spend the greater part of their time on or over the water, disseminate millions of tapeworm eggs each in the waters of the lake. It is known that eggs of other dibothria hatch out in the water, where they swim about for some time, looking much like ciliated infusoria. Donnadieu found in his experiments on the adult dibothria of ducks that the eggs hatched out readily in warm water and very slowly in cold. If warm water, at least water that is warmer than the prevailing temperature of the lake, is needed for the proper development of these ova, the conditions are supplied in such places as the shore system of geysers and hot springs on the west arm of the lake, where for a distance of nearly three miles the shore is skirted by a hot spring and geyser formation with numerous streams of hot water emptying into the lake, and large springs of hot water opening in the floor of the lake near shore.

Trout abound in the vicinity of these warm springs, presumably on account of the abundance of food there. They do not love the warm water, but usually avoid it. Several persons with whom I talked on the subject while in the park assert that diseased fish—that is to say, those which are thin and affected with flesh-worms—are more commonly found near the warm water; that they take the bait readily, but are logy. I frequently saw pelicans swimming near the shore in the vicinity of the warm springs on the west arm of the lake. It would appear that the badly infested or diseased fish, being less active and gamy than the healthy fish, would be more easily taken by their natural enemies, who would learn to look for them in places where they most abound. But any circumstances which cause the pelican and the trout to occupy the same neighborhood will multiply the chances of the parasites developing in both the intermediate and final host. The causes that make for the abundance of the trout parasite conspire to increase the number of adults. The two hosts react on each other and the parasite profits by the reaction. About the only enemies the trout had before tourists, ambitious to catch big strings of trout and photograph them with a kodak, began to frequent this region, were the fish-eating birds, and chief among these in numbers and voracity was the pelican. It is no wonder, therefore, that the trout should have become seriously parasitized. It may be inferred from the foregoing statements that the reason why the parasite of the trout of Yellowstone Lake migrates into the muscular tissue of its host must be found in the fact that the life of the parasite within the fish is much more prolonged than is the case where the conditions of life are less exceptional.

The case just cited is probably the most signal one of direct injury to the host from the presence of parasites that I have seen. I shall enumerate more briefly a few additional cases out of a great number that I have encountered in my special investigations on the entozoa of fishes for the United States Fish Commission.

The codfish very commonly harbors a dibothrium (*D. rugosum*), which fixes itself firmly in a branch of the pyloric cœca, the chain of proglottides extending into the intestine. In all cases that I have seen the head and anterior portion of the body of the worm have been firmly impacted in a yellowish, waxy secretion, which is, in part at least, derived from degenerated tissue of the cœcal appendage. These parasites must interfere seriously with the digestive processes of their host, and therefore by just so much impair its vitality. I have found the striped bass (*Roccus lineatus*) about Woods Holl, Mass., almost without exception, infested with a thorn-head worm (*Echinorhynchus proteus*). These parasites are always attached, often to the number of several hundred, firmly to the walls of the large intestine of their host. In most cases the thorny proboscis and inflated portion of the neck have penetrated the intestinal walls and protrude into the body cavity, where they are covered by a waxy secretion from the tissues of their host. This boring process gives rise to considerable inflammation, and the rectum of the fish is usually much inflamed. Evidently these parasites, in addition to the disadvantage to which they subject their host by their passive presence, not infrequently work them positive harm and lessen their chances, by some not inconsiderable increment, of long life with all that that means to the species in the life race. My check-list shows that I have examined this fish nine times in the course of several successive years, and have obtained this particular echinorhynchus in all but one lot.

Almost every specimen of such common food-fish as *Cynoscion*, *Pomatomus*, *Roccus*, etc., that I have examined, has been found to harbor a greater or less number of larval forms, of which the genera *Rhynchobothrium*, *Tetrarhynchus*, and *Syndesmobothrium* are most common. Frequently one will be found which is so badly parasitized that it is quite evident that the fish is obliged to expend a considerable stock of its own vitality to nourish its uninvited guests.

In the autumn of 1889 Dr. David Starr Jordan found an interesting case of parasitism in some young suckers (*Catostomus ardens*) which he had collected in Witch Creek, a small stream which flows into Heart Lake, in the Yellowstone National Park. Specimens of these parasites were sent to me for identification. They proved to be a species of ligula, probably identical with the European *Ligula simplicissima* Rud., which is found in the abdominal cavity of the tench. On account of its larval condition, in which it possesses few distinctive characters, I described it under the name *Ligula catostomi*. These parasites grow to a very large size when compared with the fish which harbors them, often filling the abdominal cavity to such a degree as to give to the fish a deceptively plump appearance. The largest specimen in Dr. Jordan's collection measured, in alcohol, 28.5 centimeters in length, 8 millimeters in breadth at the anterior end, 11 millimeters at a distance of 7 millimeters from the anterior end, and 1.5 millimeters near the posterior end. The thickness throughout was about 2 millimeters. The weight of one fish was 9.1 grams, that of its three parasites 2.5 grams, or 27½ per cent the weight of the host. If a man weighing 180 pounds were afflicted with tapeworms to a similar degree, he would be carrying about with him 50 pounds of parasitic impedimenta.

In the summer of 1890 I collected specimens from the same locality. A specimen obtained from a fish 19 centimeters in length, measured while living 39.5 centimeters in length and 15 millimeters in breadth at the anterior end. Another fish, 15 centimeters in length, harbored four parasites, 12, 13, 13, and 20 centimeters long, respectively, or 58 centimeters aggregate. Another fish, 10 centimeters long, was infested with a single parasite which was 39 centimeters in length.

These parasites were found invariably free in the body cavity. Dr. Jordan's collections were made in October and mine in July of the following year. Donnadieu has found that this parasite most frequently attains its maximum development at the end of two years. It is probable, therefore, that Dr. Jordan and I collected from the same generation. Since these parasites, in this stage of their existence, develop, not by levying a toll on the food of their host, after the manner of intestinal parasites, but directly by the absorption of the serous fluid of their host, it is quite evident that they work a positive and direct injury. Since, however, they lie quietly in the body cavity of the fish and possess no hard parts to cause irritation, they work their mischief simply by the passive abstraction of the nutritive juices of their host, and by crowding the viscera into confined spaces and unnatural positions. The worms, in almost every case, had attained such a size that they far exceeded in bulk the entire viscera of their host.

From the fact that the examples obtained were of comparatively the same age, it may be justly inferred that the period of infection to which the fish are subjected must be a short one. I did not discover the final host, but it is almost certain to be one or more of the fish-eating species of birds which visit that region and presumably one which, in its migrations, pays but a brief visit to this particular locality. This parasite was found only in the young suckers which inhabit a warm tributary of Witch Creek. They were not found in the large suckers of the lake. These young *Catostomi* were found in a single school, associated with the young of the chub (*Leuciscus atrarius*), in a stream whose temperature was 95° F. near where it joined a cold mountain brook, whose temperature was 46° F. We seined several hundred of these young suckers and chubs, ranging in length from 6 to 19 centimeters. The larger suckers were nearly all infested with these parasites, the smaller ones not so much, and the smallest scarcely at all. Or, to give concrete examples: of 30 fish ranging in length from 14 to 19 centimeters, only one or two were without parasites; of 45 specimens averaging about 10 centimeters in length, 15 were infested and 30 were not; of 65 specimens averaging about 9 centimeters in length, 10 were infested and 55 were not; of 62 specimens less than 9 centimeters in length, 2 were infested and 60 were not. None of the chubs were infested with this parasite.

The conditions under which these fish were found are worthy of passing notice. The stream which they occupied flowed with rather sluggish current into a swift mountain stream, which it met at almost right angles. The school of young chubs and suckers showed no inclination to enter the cold water, even to escape the seine, but would dart around the edge of the seine, in the narrow space between it and the bank, in preference, apparently, to taking to the colder water. When not disturbed by the seine they would swim up near to the line which marked the division between the cold and the warm water, and seemed to be gazing with open mouth and eyes at the trout which occasionally darted past in the cold stream. The trout appeared to avoid the warm water, while the chubs and suckers appeared to avoid the cold water. It may be that what the latter really avoided was the special preserve of the trout, since large chubs and suckers are found in abundance in the lake, which is quite cold, a temperature of 40° F. having been taken by us at a depth of 124 feet.

Since the eggs of this parasite, after the analogy of closely related forms, in all probability are discharged into the water from the final host and hatch out readily in warm water, where they may live for a longer or shorter time as free-swimming, planula-like forms, it will be observed that the sluggish current and high temperature of the water in which these parasitized fish occur give rise to conditions which are highly favorable to infection.

It may be of passing interest to state here what I have recorded elsewhere, that ligulæ, probably specifically identical with *L. catostomi*, form an article of food in Italy, where they are sold in the markets under the name *maccaroni piatti;* also in southern France, where they are less euphemistically but more truthfully called the *ver blanc.* So far as my information goes, this diet of worms, like the historical episode of that name, is strictly European.

It is not necessary to prove cases of direct injury resulting from the presence of parasites in order to make out a case against them. In the sharp competition which nature forces on fishes in the ordinary struggle for existence, any factor which imparts an increment either of strength or of weakness may be a very potent one, and in a long term of years may determine the relative abundance or rarity of the individuals of a species. In most cases the interrelations between parasite and host have become so adjusted that the evil wrought by the parasite on its host is small. Parasitic forms, like free forms, are simply developing along the lines of their being, but unlike most free forms they do not contribute a fair share to the food of other creatures. I have been too busy with the practical work of describing actual species to speculate on the question of their utility, and, moreover, have had no experience in teleological reasoning. It does appear to me, however, that if the question could be referred to all the rest of animated creation, there would be practical unanimity in the declaration that those animals which pass all or the greater part of their existence as parasites are supremely unnecessary.

IV.

I am sometimes asked substantially this question: Of what use is the study of these comparatively obscure forms? In answer I must admit that a large majority of the species belonging to the orders *Trematoda*, *Cestoda*, and *Nematoda*, which furnish about all the entozoa, have little other than a zoölogical interest. But as I understand scientific investigation it very often does not concern itself about questions of practical utility.

Again, I am asked: What remedy is proposed for those cases of parasitism which are plainly injurious? A few remarks on the subjects suggested by these two questions may not be inappropriate. As to the utility of helminthological investigations, it may be said that they stand in the same category as any other scientific investigation. Where there is exhaustive knowledge of the thing itself the application of that knowledge towards getting good out of it or averting evil that may come from it first becomes possible. For example, a knowledge of the life-history of *Trichina spiralis* and its pathological effects on its host has taught people a simple way of securing immunity from its often deadly effects. A knowledge of the life-histories of the various species of tæniæ which infest man and the domestic animals, frequently to their serious hurt, has made it possible to diminish their numbers, and may in time lead to their practical extinction.

So with the parasites of fishes. Whenever for any reason or reasons parasitism of any sort becomes so prevalent with any species as to amount to a disease, the remedy will be suggested, and in some cases may be practically applied. If, for example, it were thought desirable to counteract the influences which are at work to cause the parasitism of the trout of Yellowstone Lake, it could be very largely accomplished by breaking up the breeding-places of the pelican on the islands of the lake. With regard to parasitism among the marine food-fishes, the remedy, while plainly suggested by the circumstances, might be difficult of application. Yet something could be done even there, if it were thought necessary to lessen the amount of parasitism. If such precautions as the destruction of the parasites which abound in the viscera of fish before throwing them back into the water, and if no opportunity be lost of killing those sharks which feed on the food-fishes, two sources of the prevalence of parasites would be affected and the sum total of parasitism diminished. These remarks are made not so much because such precautions are needed, as to suggest possible applications of knowledge which is already available.

Some parasitic forms, however, are and must remain ineradicable, for the reason that food-fish are their final hosts, and the intermediate hosts are a necessary food of the fish. For example, the intermediate hosts of certain echinorhynchi which infest some species of fish have been found to be certain small crustacea, as *Echinorhynchus proteus*, which has *Gammarus pulex* for an intermediate host; while the gasteropoda are almost universally infested with cercariæ, the larval stage of the trematoda.

V.

Some lines of investigation which suggest themselves as of importance to the science of helminthology will now be briefly treated. By way of introduction to this part of the subject in hand I wish to be indulged in a short digression. It often happens that the working helminthologist wishes to identify the host of some form which he has found. In order to do this in a great many orders of animals he is obliged to waste a great deal of time in rummaging through the ordinary books with which every good general library is supplied, and even then too often with the result that the species, not necessarily an uncommon one, can not be identified. There is certainly need among working naturalists for compilations which will enable one to do in zoölogy what he can do in botany with the aid of such works as Gray's Manual.

It is surely contrary to the spirit of true science that the acquisition of correct systematic knowledge in zoölogy should be limited to the vicinity of large libraries, or that there should be an hierarchy of specialists to whom we must go in order to learn the systematic position of every form that is at all unusual. Morphological and embryological investigations are of the greatest importance, and in the end must be depended on in testing and revising the work of the systematist; but is there not danger that in all this anxiety about cell division, panmyxia, the transmissibility of acquired characters, the meaning of sex, etc., to which our most prominent biologists are giving time and talents, a generation of students is being produced who are attempting to work out problems in this country for which we are not ready? At least, while there are so many groups of animals practically untouched and so much to be done in the way of studying animals in their bionomic relations, it is certainly not unfitting to speak a word occasionally to incite to the study of nature as she is in nature and not wholly as she is in the laboratory. I am ready to confess for myself in this regard that I sin daily, for I preside as best I can over a laboratory where, to borrow an idea from my highly esteemed and most excellent friend Prof. S. A. Forbes, nature is boiled in corrosive sublimate and fried in paraffin before she is given serious study.

For the orders which are comprised in the study ordinarily designated by the term helminthology—viz, *Cestoda*, *Trematoda*, *Acanthocephala* and *Nematoda*—there is call for much preliminary work before such a compilation as I have been pleading for in other orders can be made anything like exhaustive; and this because of the little pioneer work that has been done.

In my own work I have been compelled, by stress of circumstances, to confine my collections almost entirely to the vacation months of July and August and to rather limited localities; but even here I have found material so abundant and so much of it new that I have kept thus far, for the most part, along the somewhat antiquated but still necessary path of systematic work.

Among the subjects which should engage the attention of the helminthologist who takes up the study of fish-parasites I should place first what I will call pioneer work; not because I think it to be of most absolute importance, but because it should precede other kinds of investigation. It is of supreme importance, it seems to me, to have full descriptions, accompanied with sketches, of the adult forms of entozoa which infest the fish of our waters. As much work as possible should, at the same time, be done on larval forms. Whenever larval forms can be certainly identified as the immature form of some adult, or where, as in the case of larval tetrarhynchs, there are constant adult characters present in the larva, there should be full descriptions given, always accompanied with sketches. Date of capture and name of host should, of course, be given in all cases. Incidentally these descriptions should include just as much anatomical and histological detail as the material at the disposal of the investigator and his time will permit. For most of the entozoa, which are often very variable in shape, the more detailed the description is the better. Furthermore, investigations should be carried on in every month of the year in which the fish under examination can be obtained. Notes should be made, at the time of collecting, of the food of the fish; this may lead to the discovery of the intermediate host.

Next, the life-histories of those forms which are already known, or thus become known in carrying on the pioneer work, should be made out. Enough is already known on this subject to furnish, in most cases, a working clue. In this, as in the pioneer work, attention should be given to anatomical and histological details, to which may be added, as occasion offers, embryological details. I think this order is preferable, for the reason that where the investigator is engrossed with the study of the early stages of little-known forms, there is danger of confusion resulting from the mixing of descriptions of young forms which are specifically different. This source of error is probably not so likely to arise in the case of the cestodes and nematodes as of the trematodes.

In this connection I may mention two or three cases which occur to me as worthy of further investigation. In almost every specimen of squeteague (*Cynoscion regalis*) which I have examined, I have found the cystic duct infested with young tetrabothria. They are usually attached in clusters to the wall of the duct, and apparently get their nutriment mainly by absorption from the walls of the cystic duct, through the scolex, which is provided with a special sucker. When disturbed they easily become detached and float about in the amber-yellow contents of the duct. Forms closely resembling these, though usually smaller, are also frequently met with in the intestine of the same fish. I have also found them in the intestine of the goose-fish (*Lophius piscatorius*) and in the cystic duct of a flounder. Some of them appear to be the young of an echeneibothrium. If collections were made at other times of the year than the summer, which is the only time I have had an opportunity to collect them, it should not be a difficult matter to identify them and to make out some or all of their life-history.

Another case of parasitism, or rather condition of parasitism, which calls for special investigation, is that furnished by many of the encapsuled nematodes. In the majority of fish which I have examined, I have found a greater or less number of nematodes, coiled up and enveloped in a thin cyst, and usually attached to or enveloped in the serous investment of the viscera. In many species they are few, but in some, of which *Lophius* is a notable example, they are very abundant and almost invariably present in every specimen. These encapsuled nematodes are always immature. I have been able to refer some of them to species described by Leidy and others; some agree superficially with *Agamonema communis* for example, but upon closer examination will be found to be covered by a thin investment which itself bears the distinguishing characters of *Agamonema*, while within this investment is a nematode which is plainly a rudimentary *Ascaris*.

Again, I have found specifically identical forms encysted in the body-cavity and free in the intestine of the same fish. For example I found *Dacnitis globosa* Duj. frequent in the alimentary canal, in the vicinity of the pyloric cœca, and the same species in pediculated cysts in the body-cavity of the same fish, *Salmo mykiss*. Special attention should be given to these encapsuled, encysted, and immature nematodes. The investigations should be made to cover as many months of the year as possible, and attention should be given to details of structure, since the immature stages of this order have few distinguishing features that can be made use of in classification.

Another nematode, which I have collected a few times, shows such a remarkable difference between the young and the adult as to call for special study. This is a filaria of considerable length which I have found on the ovaries of *Pomatomus saltatrix* and of *Lobotes surinamensis*, a description of which will be given in a forthcoming paper. I have received the same worm in a collection of entoza from the United States National Museum. The host in this case was *Megalops thrissoides*. This worm grows to great length. One specimen from *Lobotes* measured 580 millimeters. The aggregate length of the fragments from *Megalops* was over 3 meters, the diameter about 1 millimeter throughout. The adult worm is bluntly rounded anteriorly and tapers to a blunt point posteriorly. It is viviparous and contains, on account of its great length and the small size of the young, from 0.2 to 0.36 millimeter in length, an enormous number of young. The latter are somewhat long-clavate in shape, thickest posteriorly, bluntly rounded at posterior end, while anteriorly for about one-third of the entire length they taper to an exceedingly minute, attenuate point. The young thus resemble the genus *Trichosoma* in outline. Whether these young filariæ make their escape from the parent and penetrate the tissues of the host, or whether they must await the ingestion of their host by some other animal before they are liberated to begin a new life, I do not know. It is certain, whatever their ultimate fate may be, that no one would suspect them of being the young of the filaria which gave them birth if they had not been seen in the uterus of the parent.

Lastly a very careful examination of the invertebrate food of fishes for larval parasitic forms should be made, so as to be able at last to determine the intermediate host or hosts of all the known adult forms.

It is not at all unlikely that some practical results would follow such investigations.

WASHINGTON AND JEFFERSON COLLEGE,
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16.—ON THE FOOD OF THE MENHADEN.

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The studies of the menhaden (*Brevoortia tyrannus*) upon which this paper is based were made at the station of the U. S. Fish Commission at Woods Holl, Mass., during the summer of 1893, the material for this purpose having been collected in the same general region between July 10 and September 10. Menhaden were comparatively scarce in this vicinity during the period mentioned; no specimens were obtained from the open waters of Vineyard Sound and very few from Buzzards Bay, but in the smaller tributary bays, brackish-water estuaries, and shallow lagoons they were present, and sometimes abundant, as in the mouth of the Acushnet River, at New Bedford, where they spend the entire summer within a comparatively small area. The same may also be said of most of the other brackish-water inlets investigated, as explained below.

The material thus studied is therefore quite sufficient to demonstrate the general character of the food of this fish, together with some of the details. It also illustrates the mechanism by which the food is obtained; and leads finally to some understanding of the organisms of these inshore localities as bearing upon the life-history of the menhaden directly, both as to the time and place of spawning, and as furnishing an appropriate food supply for both adult and young fry—within much protected areas.

The food of the menhaden is to be found in the unicellular organisms, both vegetal and animal, which swarm in all surface waters, together with the smaller crustacea and other free-swimming forms which there congregate, and there are reasons why the regions here considered—the brackish, even almost fresh, waters of broad shallow estuaries and inlets, connecting with the sea only by narrow channels—are very important as affecting the kind and abundance of the various microscopic organisms used by this fish as food. It is here that the fresh-water streams are first brought into the ocean, bringing with them a new source of the inorganic materials—in solutions drained from large land areas—which are so essential to the growth of vegetal cells and animal tissues. By these streams also are brought a wealth of fresh-water microörganisms of the most important nature, especially the *Protophyta*, which thus lend an additional source of food material to the individuals already upon the ground, or find in them new victims for their own sustenance. Salt-water organisms are also brought in with each tide, giving a new intensity to the struggle; it is the common

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NOTE.—The paper read by Mr. Peck at the Fisheries Congress was a brief of a report then under preparation by him. The full report, having since been completed, is presented here in lieu of the abstract.

meeting-ground for both salt and fresh water forms, with constant additions from each source, resulting in the closest interaction of all, and the consequent thriving of some particular forms.

Again, the purely physical conditions tend to make these inlets an important swarming-ground for unicellular life, together with the many organisms depending in close connection upon it. The depth of the water is never great, and it is therefore the first to be warmed in the springtime, and is most completely warmed in the summer. The sun's rays penetrate to the bottom and are again reflected; bottom organisms flourish well, contributing a new class of free-swimming larval and adult material. Great banks of eelgrass, lying half exposed at low tide to the summer sun, are hotbeds of growth, and harbor an untold complexity of minute organic forms which often cover each blade of the grass with a living slime. The meshes of our gill nets left down during one night were in many cases coated over with the greenish and brownish algous slime gathered by the flowing of one tide through them. These localities are also (according to all the data available at present) the protected retreats into which this species of fish retires at its spawning season in the early summer, and in which the earliest stages of the young are passed.

These minute organisms furnish directly the food of the menhaden, not only within the limits of these brackish-water inlets and estuaries where the spawn is left to develop, but also wherever the fish is found in the more open coast waters. The whole food supply of this fish is obtained by filtering out from the surface stratum of water the organic life there suspended.

The mechanism by which the menhaden secures this character of food is admirably fitted for such a purpose in the high specialization of the "gill-rakers," which are so complete as to render the whole pharyngeal cavity capable of filtering large quantities of water, which the fish takes in—as has often been observed—by swimming actively in circles through the water, with widely-opened mouth and expanded opercula.

I have given in plates 1 and 2 five figures to illustrate this mechanism. Fig. 1 is an outline (two-thirds natural size) of the adult menhaden in its attitude of swimming through the water for food; in the pharyngeal cavity, underneath the opercula, are indicated the positions of the five gill-arches (*1*, *2*, *3*, *4*, *5*) of the right-hand side of the animal; the five corresponding gill-arches of the opposite side of the throat cavity are omitted in the diagram. In fig. 2 are represented the five gill-arches, with all their parts, of a somewhat larger specimen (drawn two-thirds natural size) removed from the fish and placed in order, one behind the other, in a series, of which *A* is the most anterior, the others, *B*, *C*, *D*, following to *E*, the small rudimentary one, which is the most posterior. Attached to the axial gill-arches *1* to *5*, upon the anterior edge of each, is the row of fine stiff gill-rakers *a*, *b*, *c*, *d*, *e*, arranged in a close parallelism like the barbs upon the shaft of the bird's feather, which, indeed, they closely resemble in appearance. These are relatively very long, reaching far forward upon the inner face of the mouth cavity on the right-hand side, the left side of course having a corresponding set attached in like manner to the bony gill-arches as axes. Projecting backwards from these gill-arches are also the regular double-rowed lamellæ of branchial filaments *m*, *n*, *o*, *p*, the respiratory apparatus proper of the fish; the last gill-arch *5*, however, carries no branchial filaments.

If now these be telescoped together into their natural position in the sides of the mouth cavity of the fish, then *A* will be the most anterior; *B*, *C*, *D*, *E* will follow in a closely arranged series; the branchial filaments *m*, *n*, *o*, *p*, each overlapping its next posterior neighbor, will be next the operculum which covers them. In like manner the gill-rakers *a*, *b*, *c*, *d*, each underlapping its next anterior neighbor, will cover the the interior surface of the mouth cavity, and this in a very perfect manner. The gill-rakers of *A* all project straight forward (*a*); those of *B* (*b*) upon the upper section of the gill-arch curve upward, as in fact the remaining members of the series all do (*b*, *c*, *d*,) in order to reach up to the upper section of each preceding gill-arch.

Reference to the diagram (fig. 1) of the gill-arches in place will show that they project downwards into the roof of the mouth, each one hanging lower down than the one preceding it; and the curving upward of the gill-rakers upon the upper section of each of the three arches (*2*, *3*, *4*) makes such an arrangement as to completely cover the roof of the mouth with these curving gill-rakers from the protruding gill-arches. Upon the upper section of gill-arch *3* is indeed a double row of gill-rakers; the regular series of upward curving ones—the continuation of *c* projecting from the upper segment of this arch—to which is added another one (*x*) projecting downward and backward to meet *y* of the next posterior series. (Part of the series *c* is omitted in the drawing in order to expose series *x* to view.) The lower edge of *x* therefore fits into the edge of series *y*, which curves abruptly upward to meet it. The rudimentary gill-arch *5* carries a short and stiff row of gill-rakers only. If the mouth of a menhaden be opened the observer is confronted by a throat cavity completely lined with a layer of these beautifully adjusted lamellæ of gill-rakers, overlapping each other in the most perfect manner—as I have attempted to explain in the foregoing; their function, namely, that of extracting food from the water, is as perfectly performed as the sequel will, it is hoped, aid in showing.

The water passing into the mouth of the fish will pass through this system of gill-rakers and make its exit posteriorly from under the opercula. The water passing through the gill-slit between *m* and *n* will be filtered by the series of gill-rakers *b;* the water passing through the gill-slit between *n* and *o* will be filtered by *c;* the water passing through the gill-slit between *o* and *p* will be filtered by *d*, *y*, *x;* in each case, of course, the upper portion of the gill-arches with their filaments will be bathed by a large part of the water as it passes through. That the column of water in so passing through this apparatus may be deprived of the organisms living in it is made evident by the finer structure of the gill-rakers themselves, as illustrated in the other figures of plate 2. They constitute rows of thin elastic bony blades arranged upon the anterior edge of each gill-arch, as before described; fig. 3 represents the basal part of six of the gill-rakers attached to their support; their full length is not, however, given. Each individual blade—covered with a delicate epithelium, in which are mucus and large-branched pigment cells—is provided with two rows of hooked barbs, one row upon either of its sides, which so project in between from all of the adjoining gill-rakers as to guard each interspace with two rows of these barbs. A diagram of these gill-rakers in cross-section is given in fig. 5, showing the attachment of the barbs to the exterior (toward the operculum) edge of each gill-raker blade, allowing them to project inwards toward the current of water passing through the mouth cavity of the fish. Finally, in much higher magnification, 178 diameters, are given, fig. 4, six of the hooks or barbs as they are attached to a gill-raker blade, showing that each of these, again, has a serrated tip. Fig. 4 is drawn to the same scale as the organisms figured in the other plates hereafter described, whence it is evident that the organic materials are easily secured by such an apparatus—the fineness, elasticity, strength, and least possible resistance of which are evident.

The whole interior of the mouth is always abundantly supplied with a mucous secretion, which aids in the accumulation of the fine food particles as they are strained from the water, and also aids no doubt in conveying them back to the œsophagus. There is also a delicate fold of the mucous membrane running along each gill-arch at the base of the series of gill-rakers, making there a deep channel, but whether there are definite ciliated tracts with this function of conveying solid particles is not as yet known. One always sees, moreover, in examination of these barbs, more or less food material clogged in their meshes, showing again the manner in which it is lodged by them. The cavity of the back part of the pharynx of the fish narrows abruptly to an apex which, guarded by a constrictor muscle, opens directly into the folded stomach of the fish.

The comparatively empty condition of the menhaden stomach has often been noted, as also the presence of a greater or less quantity of what appears to be a dark greenish or brownish mud, with a variable quantity of copepods and small crustacea intermixed, although these latter may be almost entirely absent. This apparent mud, however, is made up of the various organic matters which are always suspended in surface waters, and which the fish, by means of the filtering mechanism of gill-rakers just described, has removed from the water in which he has been feeding. This may be demonstrated not only by observing the habits of the fish when living, and by a study of the gill-rakers, but also by collecting through a filter the organic matter suspended in a given quantity of surface waters* from the localities where the fish are taken, and then by comparing such a filtrate with the stomach contents of the animal. Studies carried on in this comparative manner show very well how wide a range of microörganic forms contribute to the sustenance of the menhaden, how they are to some extent localized, and finally some of the ways in which they interact upon each other, besides serving as food to the fish.

One of the richest feeding-grounds of the menhaden studied during the season was in the estuary of the Acushnet River at New Bedford, Mass., as it was here also that the food in the earlier part of the season was of the most complex character. In a mass of food taken July 12 from the stomachs of two dozen fish one could readily find a few small annelids of the genus *Nereis*, measuring about a half inch in length usually; a few rotifers of the genus *Notomata* as nearly as they could be identified; quite a wide range of the smaller crustacea—small amphipods (*Gammarus*), young schizopod shrimps, a few ostracoda (*Evadne*), a few *Zoea* larvæ, with quite abundant *Nauplius* larvæ of different species. It may here be stated of the above-named organisms, that they are more abundant in fish taken during the night. I have never noticed young annelids in fish taken in the seine by daytime, while the crustacea are also less abundant; especially noticeable is the lack of schizopod shrimps, the fewer copepods. But by far the most constant features of the menhaden food in this district are the unicellular elements in it, especially the unicellular plants, and of these the various genera of the family *Peridinium* easily predominate.

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* This was done in the course of this investigation by means of a filter, such as is used by Mr. G. W. Rafter, of Rochester, the Board of Health of Massachusetts, and the Laboratory of the Western Division of the Boston Waterworks, etc., made from a large funnel whose tube is closed at the lower end by a coil of fine wire gauze; upon this plug of gauze rests a ½-inch stratum of fine white sand upon which the organisms collect as the water filters through; from the sand the material is washed out in a given small quantity of water.

In plate 3, fig. 7, is represented a camera drawing of one field of the microscope, under a magnification of 178 diameters, of the organisms as they appear in the material collected from the surface waters of this estuary by means of the sand filter just described. The great majority of the organisms are *Glenodinium*, some of the most characteristic of which are shown at *p*, fig. 7, in the various positions of the cells. A good description of the characteristics of the marine *Peridinium* and the life-history has been given by George Klebs,* and it is easy to make out the general plan of their structure in this material. There are also taken at the surface here other pear-shaped alga swarm-spores *r*, besides many diatoms, of which, however, only a few are here shown. The *Infusoria* are an important factor in this surface material; some are the small green (*t*) which are very numerous; most abundant, however, are the small bean-shaped flagellates (*s*), which go winding their way in among the other material upon the slide when all else is motionless. All these organisms finally are mixed together in a greater or less quantity of amorphous matter—flocculent bunches of greenish and yellowish color, just such as are to be found in filtering any surface waters. Dr. W. T. Sedgwick tells me that in his opinion the color of this is due to the presence of bacteria masses of the *Zoöglea* form. There is also no doubt the detritus from disintegrating organic material of many kinds. All this matter is highly phosphorescent when concentrated upon the sand in the tube of the funnel in the course ot filtration, as may be seen by disturbing it in the darkness.

Compare now with fig. 7, fig. 8, which represents in a similar manner one field of the microscope drawn with camera, exhibiting the same organisms taken from the stomach of a menhaden; the fish was feeding in the locality just mentioned where the surface waters were filtered. The same *Peridinium* is present and in the same large proportion to the other forms of living material, except that the smallest organisms—infusoria, etc., of fig. 7—do not appear in this material to any great extent. This may be due to the fact that the very smallest actively moving organisms may pass through the meshes of the pharyngeal filter, which may be readily conceived on account of their minute size, or they may be so mixed up in the mucous and amorphous matter in the fish's stomach as to escape detection to a great extent. It is easy to see the complete identity between living organisms filtered from water by mechanical contrivance and those secured by the menhaden feeding in the same waters by means of his anatomical specialization, giving a demonstration that the menhaden is a surface feeder—taking the organisms suspended in the water in a very complete manner.

It must not be imagined from the foregoing figures that the waters there contain no other organisms than *Peridinium;* the percentage of diatoms is very great, not to mention the annelids, rotifers, and crustacea, before enumerated, which latter were (except the crustacea) found only in this locality in the stomach contents of the fish. In fig. 16, pl. 7, are represented some of the more important diatoms selected from the food taken from several fish in this locality; there is also an occasional alga thread, as also oscillatoria threads. One large foraminifer was also found in the food, belonging to the genus *Discorbina.*

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*In the Botanische Zeitung, Nos. 12 and 14, 1884.

Applying the same methods of procedure—*i. e.*, comparing the organic matter filtered from the water with that found in the alimentary tract of the fish—to other localities, it will be seen that the organisms have certain local variations, with which the stomach contents of the menhaden are again in close agreement. For instance, the fish taken within the southeastern corner of Buzzards Bay have contained within their stomachs organic food-stuffs which agree completely within themselves and with the microörganisms free-living in the water where they were taken. It may be observed that the quantity of food here present was much less than in those fish which had been feeding in the brackish waters of other regions; indeed, one fish which had taken its food during the night at New Bedford—which therefore included a large proportion of the smaller crustacea—contained four times as much food as ten fish taken in the pounds in this corner of the bay. This is an extreme case, however, for a fish feeding at daytime in the estuary contains less food than one feeding at night; while the Buzzards Bay fish, entrapped in a pound, may have digested up a large part of his stomach contents during the night before being taken for examination. But it is undoubtedly true that the food supply of a fish in the open waters of the bay is less than that of one feeding in the estuary before named. This is evident by comparing the organic material filtered from a given quantity of surface water from each region; also from the contents of the stomach, and from the relative weight of fish of the same length in the two regions—the fish from the bay weighing less for their length than the fish from the Acushnet estuary or any other brackish-water locality. An illustration of the extent of these differences is given in the outline drawings, one-half natural size, of plate 8; fig. 17 was from a fish taken July 20, at Woods Holl, Mass., in Buzzards Bay; fig. 18, from a fish taken August 25, at Waquoit Bay, a large protected inlet with narrow opening to the sea, in which the microörganic life was very abundant. The organisms from the water of Buzzards Bay may be judged from plates 4 and 5. The stomach contains little food and a great deal of mucus, just such as is secreted in the mouth of the fish, but the microörganisms are very characteristic. Those of three different positions of the microscope are gathered into fig. 9, giving a characteristic idea of the material in a given fish's food. There are new forms of the *Peridinium* type, the large sculptured *Peridinium* sp., at the upper edge of the field *p*, as well as the large, smooth, pinkish *Peridinium* sp. at *p* in the left central part of the field; also at *r*, half of the very much elongated *Ceratium fusus.*

Perhaps the most characteristic element of this locality, however, is the large infusorian *t* of the genus *Codonella,* of which several species are found. A review of the structure and systematic arrangement of these important organisms may be found as given by the studies of Geza Entz upon this group.* Also by the studies of Dr. Eugene V. Daday.† The *Codonella* here found were of the species which are invested with a test in which calcareous nodules are imbedded, and were exceedingly abundant in the food of the menhaden taken in this region. There is also the diatom (*e*) with the flatiron-shape, and the infusorian *m*, which hereafter becomes one of the most constant features of the menhaden food. In the same manner fig. 10 shows other representative organisms of this region, taken from fish entrapped at Woods Holl, on the bay side. At *p* is the same *Peridinium*, at *h* the infusorian *Dinophysis*, the same abundance of *m*, a *Codonella t*, some of the diatoms at *d*, all gathered into this figure from two fields of the microscope.

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* Mittheilungen aus der Zoologischen Station Zu Neapel, Bd. 5, 1884, p. 389. Ibid. Bd. 6, p. 200.

† Mittheilungen aus der Zoologischen Station Zu Neapel, Bd. 7, 1886-1887, p. 473.

Organisms from the stomach of a fish taken off Naushon Island, at the Weepecket Islands, are indicated in fig. 11—from a single field under the microscope. The *Tintinnodea* (*t*) were remarkably abundant, the same diatoms as before were also very numerous, as also the *Ceratium fusus*. That these of the three preceding figures are the common unicellular organisms of the surface waters of this region of the bay in which the fish were taken is shown in fig. 12, which represents some of the surface organisms filtered out of the water of the bay by means of the sand filter before described. There are the same *Peridinium p*, *Tintinnodea t* and *v*, the same infusoria *m* and *h*, the same diatoms *Nitzschia*, *Synedra*, *Concinodiscus*, *Navicula*, etc., *d*, together with others not figured in the food material as found in the fish's stomachs, noticeably the beautiful *Chætoceros*. It is worthy of mention that the *Tintinnodea* figured were relatively more abundant in the stomachs of the fish than in the filtrate from the surface waters, and is perhaps to be explained by a different depth in which the fish were feeding; or the fish having in every case fed at night, while the water filtered was taken at daytime, these infusoria may have removed from the immediate surface at the time the sample was taken. In the food here figured the crustacean elements of it have been neglected, both because it is sometimes quite scanty and at other times very abundant, even in the same locality, and is of the same general character in all the localities studied, preëminently copepods, larval and adult. The minute crustacea are of course a favorite food of the menhaden, but no attempt has been made to illustrate it with the other organisms with which it is associated in the stomach of the fish. That is to say, those portions of the field were selected for figuring in which the crustacea were absent.

I shall, finally, illustrate this same point of the localization of littoral surface organisms by figures offering a similar comparison of some of the unicellular surface organisms from a very long lagoon of brackish water at the eastern end of Marthas Vineyard (at Vineyard Haven), in which menhaden in four different lengths, or stages of growth, were taken, showing again the identity of those organisms in the alimentary tract of the fish with those in the surrounding surface waters in which they were feeding. There is considerable difference in the prevailing types, although, of course, many of the species are common to it and all the other localities studied. Some of the organisms filtered from the surface waters are represented in fig. 13, selected from various parts of a single slide of the microscope. The diatoms are beautifully represented by the chain *d*, composed of very large individuals unknown to me; these are very abundant in this locality. Another chain, *g*, of a species unknown to me, is also quite common, as is also the genus *Lauderia* (*f*). The *Peridinium* family is represented chiefly by the large, smooth, pinkish form *divergens*, with an occasional *Glenodinium*, *r*, such as was found at the Acushnet River locality. At just below *a* is represented the empty cell wall of a small vegetal organism, unknown to me, having a peculiar rounded right-angled triangle shape, with very thick walls. The *Tintinnodea* are extremely abundant, too, in this locality, presenting a great variety of species; at *w* is a *Tintinnus*; at *v* a peculiar kind, with a spiral marking and 2 whorls of an expansion or flange on the test; those forms represented at *t* and *c* are also common. Taken altogether, this lagoon exhibited one of the richest surface faunæ studied during the summer and like the others seemed to grow even richer as the early autumn approached.

Some of the organisms in the stomach of a young fish—60 millimeters in length—are shown in fig. 14; the same genera of diatoms are present, the same *Peridinium* and infusoria, the same organism, *a*, as were found in the preceding instance, from the water filtered artificially. In an adult fish of this locality are also found the same organisms as are here portrayed in figs. 13 and 14; especially in some fish are great numbers of the *Tintinnus*. If now reference be made to fig. 6 (plate 2), an idea may be given of some of the most important organisms found in this same lagoon at Marthas Vineyard, but in a large pond shut off at its extreme upper end from the main body of water except for two very narrow sluiceway connections. Fish were here taken measuring 100 millimeters in length, and their food products represented in part in fig. 6. The lower half of the field is an exact drawing of the number (in a single field of the microscope) and position of the very abundant vegetal organism heretofore mentioned; it comprised far the greatest part of the food material. In the upper half of the drawing are represented some of the other organisms which were of common occurrence in the same material. All of these are alike found in the surface waters, and in the menhaden stomachs of this interesting locality. In these surface waters were also found many threads of fungous mycelia, also oscillatoria threads in considerable quantities.

It thus appears that young menhaden, as soon as they can be secured, indeed, in the earlier part of the season, consume the same kinds of food as the adult fish, and this holds true of the other localities considered in this work. They consume the copepods also, like their parents, in such numbers as these crustacea appear. Indeed the stomachs of the young fish show these organic food constituents in the clearest manner, since there is less mucous and amorphous matter mixed up with them. The young fish from the Acushnet estuary contain *Glenodinium* in the same abundance as do the adults, while the young fish of each locality examined led to the same conclusions; and figures drawn from the material upon the microscopic slide would not differ essentially from the figures just described.

The food of the menhaden is not confined to the brackish-water inlets, however, for by filtering the clear blue surface waters in the open channel of Vineyard Sound one can at this same season gather a very interesting array of the microörganisms such as have been here considered. In fig. 15 are represented a few of the common forms there secured, which in some respects are different in their relative kind and abundance from any other locality examined. The diatoms are represented by the large *d;* indeed, these were very abundant in the filtrate, insomuch that a brownish yellow color was given to the whole mass by reason of them. There is also very commonly the large *Chætoceros g.* The infusorian *h* (*Dinophysis*) is very common; the infusorian *m* is also common. The *Peridinium* group is represented by the very large *Ceratium tripos.* A great deal of *Ulothrix* (?) *n* is also common in this water. The copepod *Nauplius*, *y*, is given simply to indicate its relative size to the unicellular material.

The drawings can of course give no conception of the delicate sculpturing, coloring, and beautiful contour lines of these organisms, but it is hoped that the relative size may be gathered from them, as also some graphic idea of the general make-up of this interesting food and something of the form of its varied constituents. Nor has a detailed account of the systematic identification of all the organisms been attempted, but it is hoped that enough has been given to indicate to those who may be interested some of the more important elements of the protozoan and protophytan life in brackish and inshore waters. The main object of this paper is to show the importance of those groups to the life-history of the fish in question. Three other localities of similar characters (in the same coast belt of this region) were periodically studied during the greater part of the summer, in which the same general character of surface material was found and in which menhaden were feeding. In all cases, also, the same results were obtained as have been heretofore descrided, *i. e.*, the material from the alimentary tract of the fish was entirely comparable to that of the organic filtrate from the surface water. Such then is the general character of the food of these fish, and some of its differences according to littoral localities. It varies in amount also, as has been shown, but any of the coast waters contain an abundance of this microörganic life for their sustenance, as may be determined by testing a few liters of the water.

If now the mouth of an average menhaden be opened as in its natural position when feeding, its outline will form an ellipse, of which the area will be about 1.1 inches; and if his rate of progress through the water when feeding be 2 feet per second (as I have estimated from watching the habits of a small school confined in a large pool), then the fish feeding continuously would be able to strain a column of water 1,440 inches in length of the size of the fish's mouth—*i. e.*, 1.1 inches—each minute, which column of water at the surface of the Acushnet River would in July contain 6.8 gallons of water and about 3.4 cubic centimeters of the organic filtrate, such as is found in the stomach of the average fish. The average amount of food material in the stomach of the fish feeding at that time is about 3 cubic centimeters, which, according to this estimate, would be obtained from less than 7 gallons of water, and which the fish could, therefore, extract in about one minute. Of course these quantities are only estimates; the menhaden does not feed continuously, and it may be that all the water does not pass through the gill-rakers at the rate the fish swims, so that the amount of water actually filtered is doubtless considerably less; many of the smaller organisms also may escape through the meshes of the gill-rakers, so that it may take the animal longer to extract the given amount of material from the surrounding medium, while my estimate of the average amount of food in a normal fish stomach is very low for this particular locality. On the other hand, the animal swimming with widely-open mouth against the water brings some pressure to bear, and so aids in the rapidity with which the water passes backward through the pharynx—so that the above low-estimated amount filtered in a given time is by no means unreasonable for such a time as the fish does really feed.

But the estimates of the quantity of organic matter actually present in the water are certainly reliable; and allowing for all shortcomings on the estimated capacity and movements of the fish, there is still a wide margin in favor of its ability to gather a great amount of food in a short time.

The passage of the food through the alimentary tract is, however, probably very rapid, and a large quantity of this kind of food must be needed by the fish; in favorable localities the whole intestinal canal is gorged with this material. The quantity of such food, moreover, is illimitable, each cubic foot of water is charged with it, and rapidity of increase of the unicellular organisms in a geometrical ratio—their life-history being measured almost by moments—is such as to insure a stable basis of existence to those species depending upon them. Indeed, it is little wonder that these fish are so fat when their food supply is considered.

Another important consideration in the make-up of the menhaden food is its vegetal character to so great a degree. The predominance of the many species of diatoms and *Peridinium;* the swarm spores, oscillatoria, and fungous threads contribute directly to the food of the animal itself, and indirectly through the large infusoria and copepods. Of the large family of infusoria—*Tintinnodea*—so abundant in the foregoing descriptions of the menhaden food, Daday says:[*]

> Im Haushalte der Natur spielen sie durch ihre Gefrässigkeit eine ziemlich bedeutende Rolle, indem sie ausser den kleinen Diatomeen, Algen und anderen Pflanzenresten auch viele verfaulte organische Stoffe verschlingen.

He also goes on to say that they do not shun microscopic animals, but repeatedly can be found having eaten *Dinoflagellates*, *Peridinium* and *Dinophysis;* even their own relatives—*Codonella*, *Tintinnopsis*, etc. This is also no doubt true of many of the other infusoria gathered by the menhaden. In the figures of the infusoria of the Gulf of Naples[†] Entz represents very many of these organisms with diatoms within their cytopasm. The copepods, which are the most important animal constituent of the food material, feed, I am very sure very largely upon the same vegetal diet in these localities here considered as is taken by the menhaden. The alimentary tract of the copepods is filled with a greenish-yellow colored mass of material, in which one may often identify the small vegetal cell so abundant in fig. 6 (plate 2), which by reason of its minuteness has escaped the crushing up in the process of feeding by the animal. In an arm of Childs River, Waquoit Bay, it is almost certain that the abundant copepods of the surface water were filled with the small *Raphidium polymorphum*, which, together with very many other forms of oscillatoria, made a large part of the material gathered by the fish, which organism was so abundant in the stomach of the menhaden. Another important place in the elaboration of this vegetal microörganic food supply is undoubtedly filled by the bacteria, whose abundance and even presence are so unsuspected in the ordinary study of microörganisms of surface waters. Dr. H. L. Russell, speaking of the diminution of land bacteria as one leaves the shore and proceeds into dense sea water, says:[‡]

> Die gewöhnlichen Spaltpilze, welche im süssen Wasser und im Erdboden vorhanden sind, werden durch die Thätigkeit des Seewassers und der darin enthaltenen Mikroorganismen zerstört.

Dr. W. T. Sedjwick tells me that in his opinion the bacteria are freely used as food by the larger infusoria. The many bacteria in the so-called amorphous matter and those brought by fresh-water streams into brackish water do doubtless contribute no small element to the food supply of the infusorial organisms there swarming. Vegetal diet upon the unicellular plants is, therefore, very plainly to a great extent at the basis of the menhaden food;[§] while the fish subsist very largely upon those organisms directly, gathered by their pharyngeal filters, and indirectly upon the same material as it comes to them through the copepods, the various free-swimming larvæ, and infusoria.

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[*] Monographie der Familie der Tintinnodeen, p. 512.

[†] Ueber Infusorien des Golfes von Neapel, pl. 20-22. Mitt. aus der Zool. Station zu Neapel, Bd. 5.

[‡] Untersuchungen über im Golf v. Neapel lebende Bacterian. Zeitschrift für Hygiene und Infectionskrankheiten, Bd. 11, 1891, pp. 167, 213.

[§] See also Ryder, U. S. F. C. Bull. 1878, p. 242. The Protozoa and Protophytes considered as the primary or indirect source of the food of fishes.

Such being, then, the primitive character of the food supply of the menhaden, its economic relations are very important; it arrives first hand at a food supply which is the most stable, the most abundant and widely distributed of all foods, and yet so unavailable to the great majority of other species. The wide distribution and vast extent of the schools of this fish (which have been so remarkable in former years), testify to this fact, for no matter how many are aggregated together in a given area the food supply is adequate. At the same time the menhaden comes into no competition with the other food-fishes. In all the food products in the alimentary tracts of specimens examined during the time named, not a trace of vertebrate tissue was found; their presence does not threaten directly the life of any other vertebrate, nor indirectly do they bring want to others by appropriating too much of their food supply. In one instance this summer—at Hadley Harbor, Naushon Island—a small school of menhaden was seen rising to the surface directly under a school of young "silversides." The suddenness of the maneuver on the part of the former fish sent the minnows leaping out of the water and scattering in all directions, just as when the school is so invaded by enemies; as the silversides collected again, after a few moments, at the surface, at a little distance from the former spot, the action was repeated by the school of menhaden. A number of these latter were then captured and examined, but in no case, of course, had the minnows themselves been taken as food, while the large proportion of copepods in the stomachs of the menhaden would indicate that they had found their prey located by the movements of these small surface-feeding minnows. Their stomachs also contained, besides the usual quantity of microörganic life, diatoms, infusoria, and the like, which are abundant in the brackish waters of that beautiful and quiet retreat.

Not only, therefore, do the menhaden not compete with other fishes for food, but they themselves form an important factor in the food of other fishes, as has been so often observed in the bluefish, bonito, and squeteague; making available through their own life-history favorable conditions upon which the other economic fishes are borne and satisfied; bringing to them directly an elaboration of this primitive food supply here considered. To just what extent the menhaden are eaten by other food-fishes has not yet been entered into in this investigation, but evidences of its importance as bait are everywhere at hand, and for this reason, if no other, its place is an exceedingly important one in all questions involved in the study of hook-and-line fishing. The eagerness of the fishermen after menhaden for bait has been a most constant feature of the expeditions made by us during the summer after the material used in this study. One sees in the common opinion something more than a general preference for such bait; it is a real necessity in their equipment for work.

The relations of every individual organized being are so complex, the interaction of its species upon others so intimate, that the life-history of every being must have a very large circle of effects—visible and remote—not all of which may act in a directly beneficial way for all of our immediate specialized wants. So it may be with the menhaden, as with any other fish. In its method of gathering its food it does not, it is true, come into competition with other fish, but the floating eggs and minute embryos of all classes would be of a necessity swept in greater or less numbers into its mouth in those surface waters which were supporting schools of menhaden. Large schools of the latter fish moving along the coast at the spawning season of the scup and sea bass might draw largely upon the floating eggs of the latter and lobster embryos. Large schools of menhaden feeding in the brackish water over rich oyster beds might at the spawning season of the latter diminish materially the chances of so thick setting as might have been otherwise made had the fish not been present to strain so effectively the surface waters, with the chance of securing so many of the floating eggs and very young embryos. A detailed study of just these conditions has not yet been made, but such evidence as we have is negative. Along this part of the coast the scup, sea bass, and menhaden appear to be spawning at about the same time, the last fish having, however, removed up into brackish water retreats away from the other food-fishes. There are, however, large numbers of immature menhaden present which are not concerned with the business of spawning, and of whose movements as they first migrate into these waters very little is definitely known. At the season and localities covered by this work, however, there was no material found in the food products of the menhaden which was derived at the expense of other food-fishes. Nothing, indeed, was found but such minute organisms as are present in all these localities studied, and so abundant and evenly distributed through the surface waters that their quantities could never be materially diminished through being preyed upon by the menhaden. These organisms also are entirely unavailable to the great majority of fishes, but being thus taken directly by the menhaden they serve indirectly in the food supply of the many predaceous species to which *Brevoortia tyrannus* itself becomes a prey. Problems, therefore, which involve the consideration of this last species, with any regulations which are to be proposed for it, are very significant.

It may be urged, finally, that these many brackish-water inlets and estuaries, which so plentifully indent our coast, are regions of especial importance, entitled to the most careful consideration, because they are intrusted with so much embryonic and larval life of the migratory inhabitants of the coast, have such a rich and varied food supply, and are so much protected from the larger invaders. This is the only series of conditions to be treated in oyster-culture, and will prove, no doubt, to be a very important step in the study of many others. Such places, moreover, are the nearest at hand to which all regulations can be the most effectively tried, which can be made the most evident examples for public opinion.

U. S. FISH COMMISSION,
Woods Holl, Mass., September 11, 1893.

EXPLANATION OF PLATES.

PLATE 1, two-thirds natural size:

Fig. 1—Outline of adult menhaden as feeding. *1–5*, gill-arches of right-hand side in natural position.

Fig. 2—Gill-arches with branchiæ and gill-rakers attached, removed from fish and arranged in order; *1–5*, bony arches; *a*, *b*, *c*, *x*, *d*, *y*, and *e* are gill-rakers; *m*, *n*, *o*, *p*, branchiæ.

PLATE 2:

Fig. 3—Six of a series of gill-rakers attached to the gill-arch, showing the projecting rows of hooks, enlarged 50 times.

Fig. 4—Six of the hooks attached to the gill-raker, enlarged 178 times.

Fig. 5—Diagram of gill-rakers in cross-section, showing angle at which hooks project from their point of attachment in toward the throat cavity, and the current of water passing out from it.

Fig. 6—Organisms from stomach of young menhaden taken from a pond closed off from lagoon at Marthas Vineyard: *p*, *Peridinium;* *d*, *Diatoms;* *t*, *Tintinnodea;* lower half of field drawn with camera from single field of the slide, magnified 178 times.

PLATE 3:

Fig. 7—Organisms filtered from surface waters of the Acushnet river, showing at *p* the *Glenodinium* which is so abundant at this locality; *s*, very small bean-shaped flagellates; vegetal cells are also scattered over the field.

Fig. 8—Organisms from the stomach of a menhaden in these same waters, showing the predominance of the same *Glenodinium;* *h*, *Dinophysis;* drawn from a single field of the microscope, enlarged 178 times.

PLATE 4:

Fig. 9—Organisms from stomach of fish taken in Quisset Harbor, southeastern portion of Buzzards Bay; *p*, *Peridinium*, the lower two large, smooth, pink-colored individuals, having the form of the species *divergens;* *d*, *e*, diatoms; *t*, *Tintinnodea* of the genus *Codonella;* *r*, *Ceratium fusus.* Enlarged 178 diameters.

Fig. 10—Organisms from fish's stomach taken at Woods Holl, in the mouth of Buzzards Bay; *d*, diatoms; *p*, a large *Peridinium;* *h*, *Dinophysis;* *m*, an infusorian unknown to me; *t*, *Codonella.* Enlarged 178 diameters.

PLATE 5:

Fig. 11—Organisms from food in fish's stomach taken off Naushon Island, mouth of Buzzards Bay, at the Weepecket Islands (drawn with camera from single field of microscope); *t*, *Codonella;* *d*, diatoms; *r*, *Ceratium fusus;* *m*, infusorian(?). Enlarged 178 diameters.

Fig. 12—Organisms filtered from the surface waters of Buzzards Bay, in these same localities; *p*, *Peridinium divergens;* *t* and *r*, *Codonella;* *d*, diatoms, of which there is a representative of the genus *Chætoceros*, with its long protoplasmic processes; *e*, also diatoms; *h*, *Dinophysis.* Enlarged 178 diameters.

PLATE 6:

Fig. 13—Organisms filtered from the surface of Lagoon Pond, Marthas Vineyard; *d*, *g*, and *f* (*f* is *Lauderia*), diatoms in chains; *p*, *Peridinium divergens;* *r*, *Glenodinium;* *c*, *Codonella;* *w*, *Tintinnus;* *t*, allied to *Codonella;* *v*, one of the Tintinnodea unknown to me; *a*, very small vegetal cells. Enlarged 178 diameters.

Fig. 14—Organisms from the stomach of a young fish of the same locality (fish 60 mm. in length). *p*, *Peridinium divergens;* *d*, diatoms; *f*, *Lauderia;* *h*, *Dinophysis;* *m*, infusorian unknown to me. Enlarged 178 diameters.

PLATE 7:

Fig. 15—Organisms filtered from surface waters of Vineyard Sound upon a bright clear morning, August 15; *d*, large diatoms, which were very abundant in the sample of water; *g*, *Chætoceros;* *n*, *Ulothrix zonata* (?); *h*, *Dinophysis;* *c*, *Ceratium tripos.* Enlarged 178 diameters.

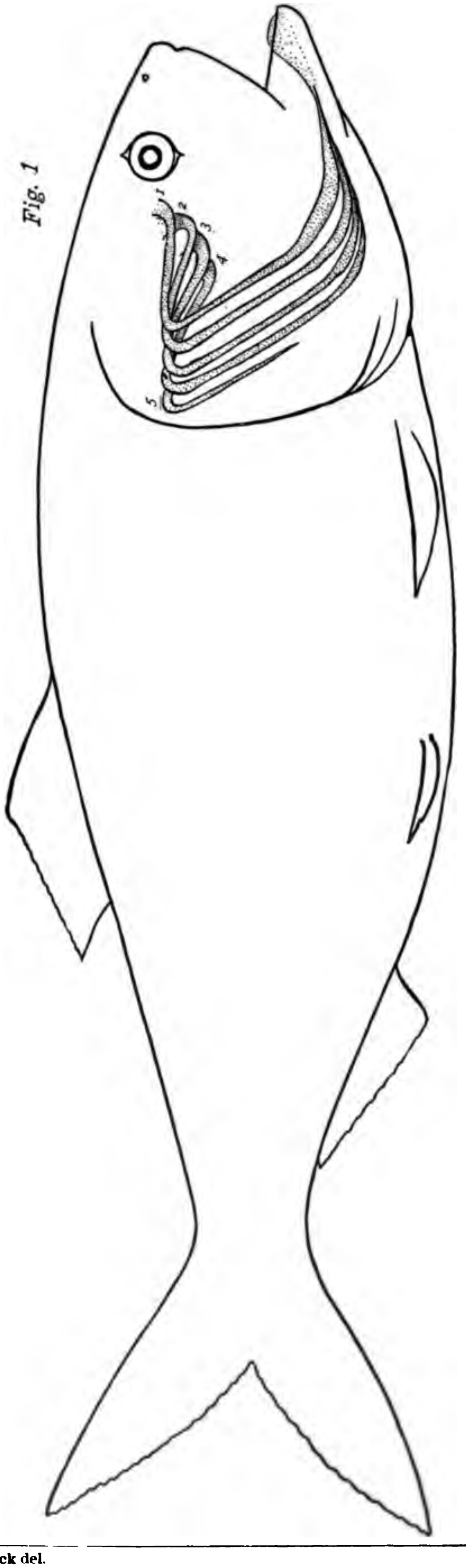
Fig. 16—Some of the organisms found in the stomachs of menhaden in the Acushnet River, in the same material figured in plate 3. *g* and *y*, alga threads; diatoms, *a*, *Triceratium;* *b*, *Bildulphia;* *c*, *Stephanodiscus* (?); *e*, *Navicula;* *j*, *k*, *Pinnularia;* *i*, unknown diatoms; *f*, *Merismopedia* (alga); *x*, *Discorbina.* Enlarged 178 diameters.

PLATE 8:

Fig. 17—Outline of an adult menhaden living in Buzzards Bay, taken July 20. One-half natural size.

Fig. 18—Outline of an adult menhaden living in the extreme upper part of Waquoit Bay, taken August 25. One-half natural size. This region was very rich in *Protophyta*, especially *Cyanophyceæ*, also *Copepoda.*

Fig. 1



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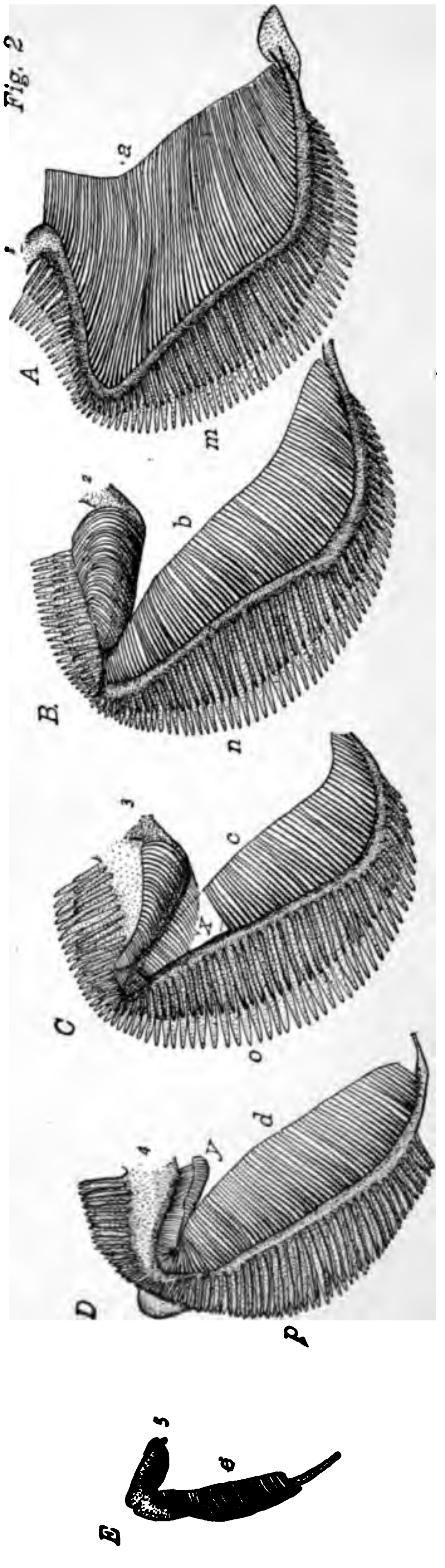

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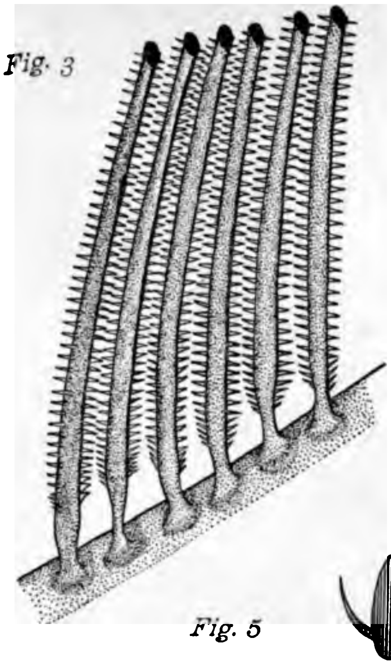
Fig. 3



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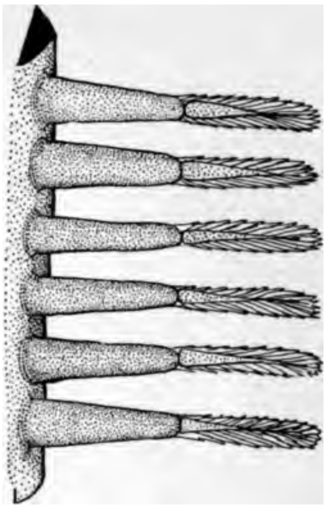

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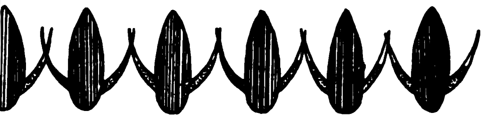

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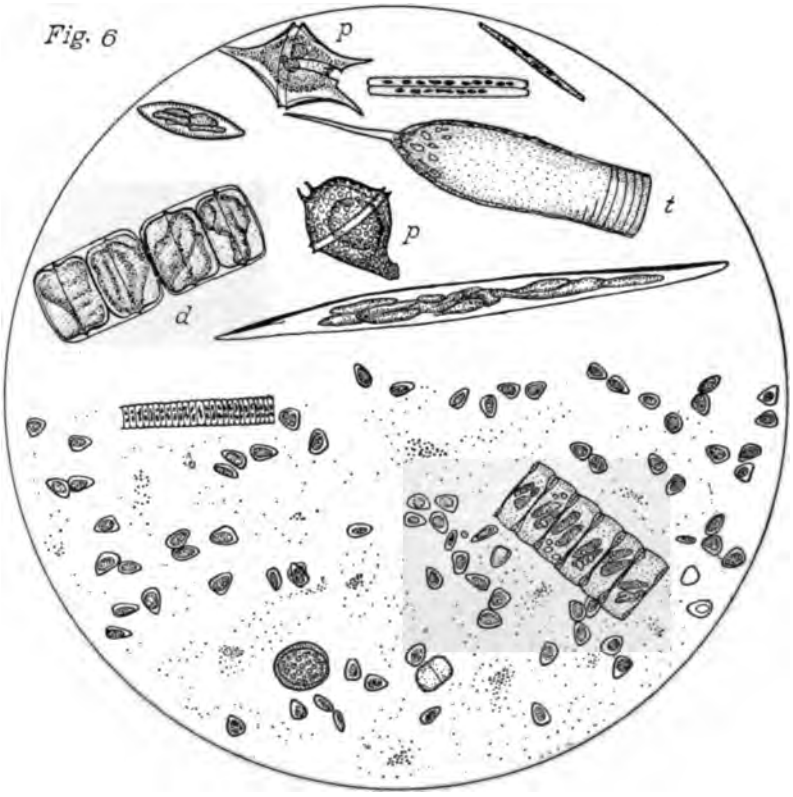

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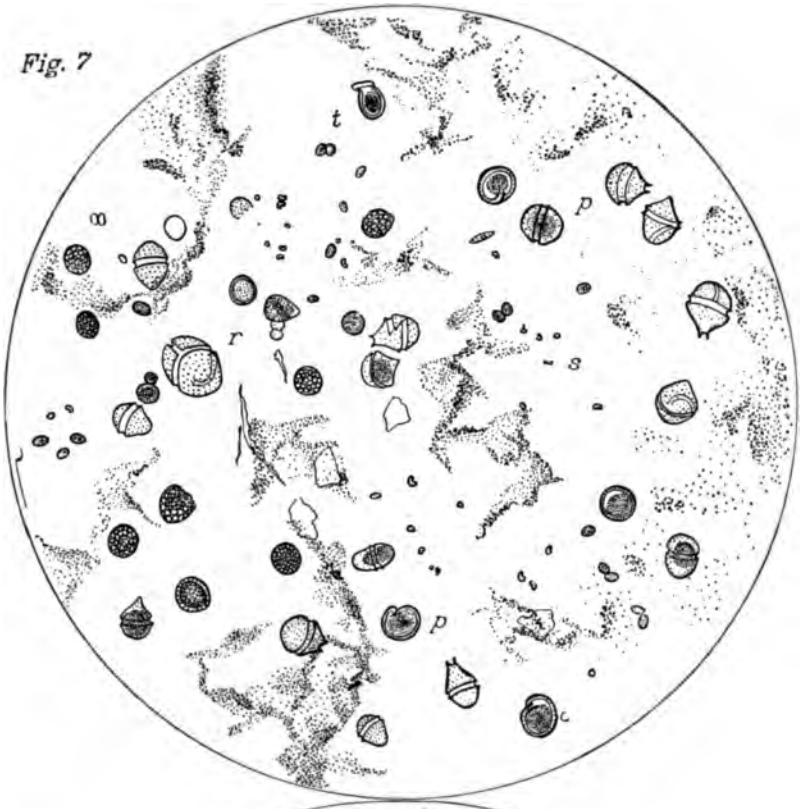

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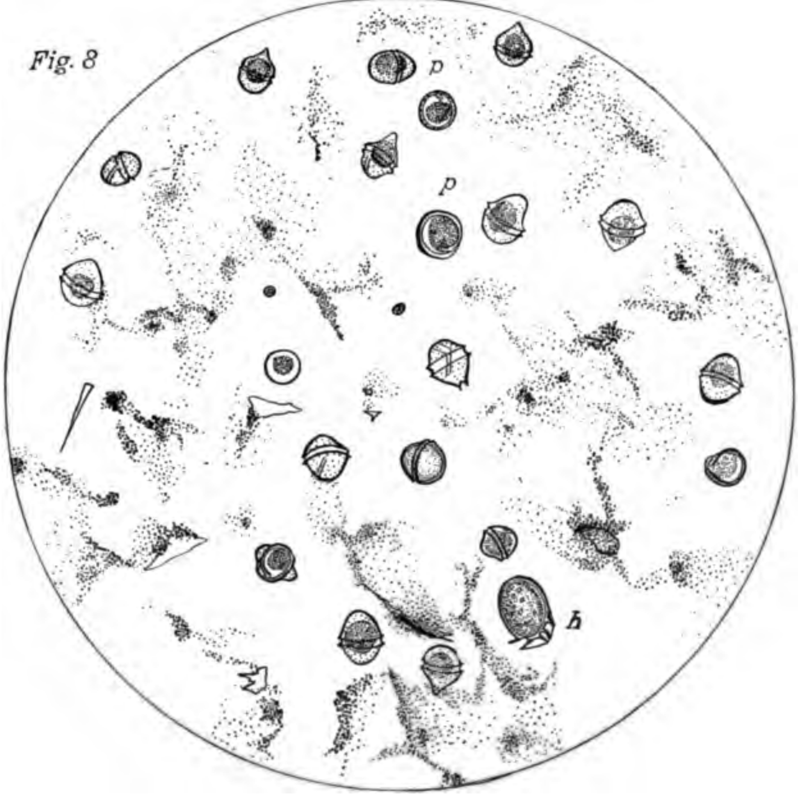

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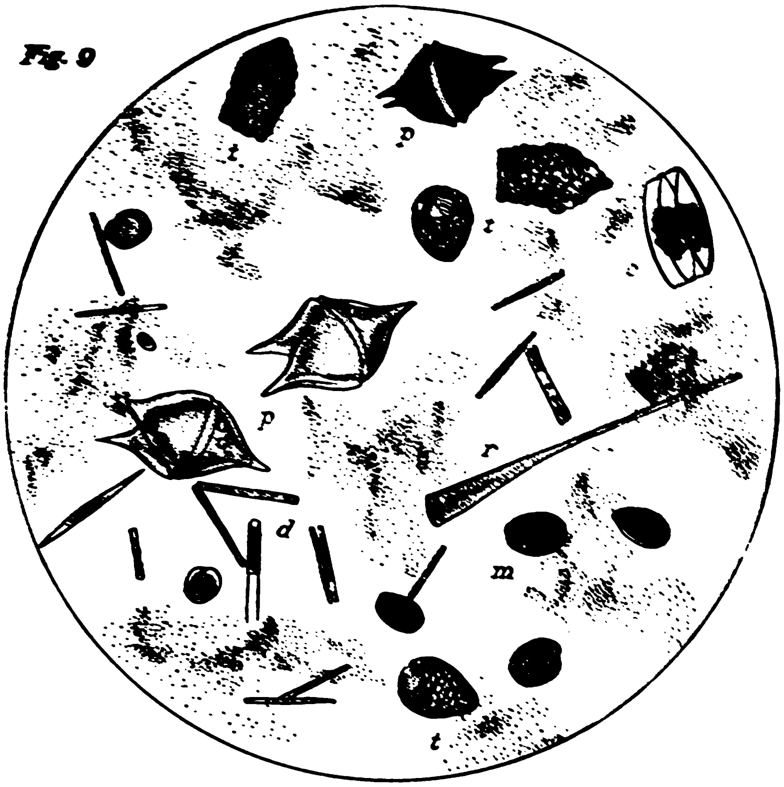

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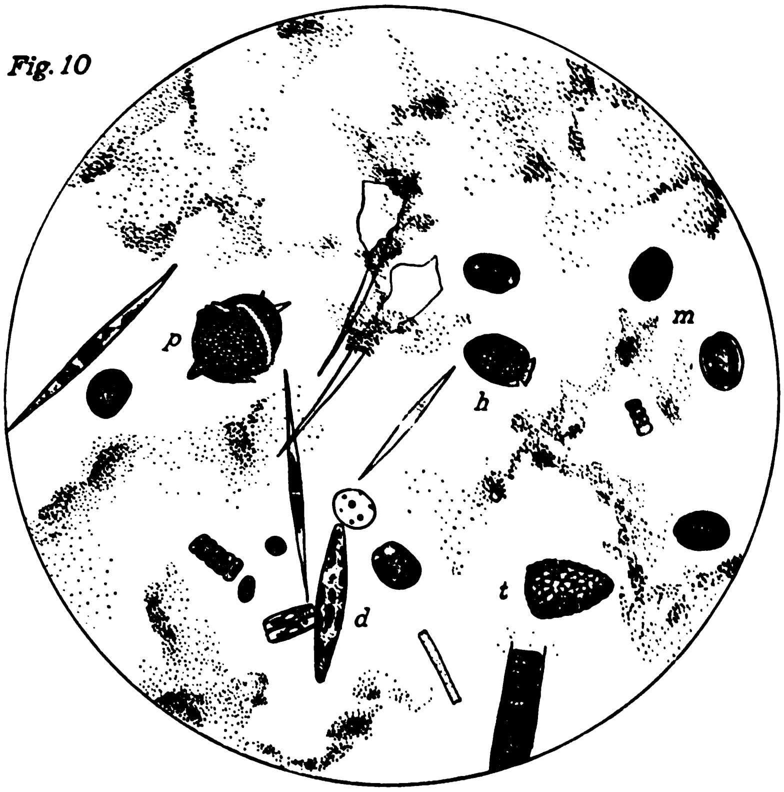

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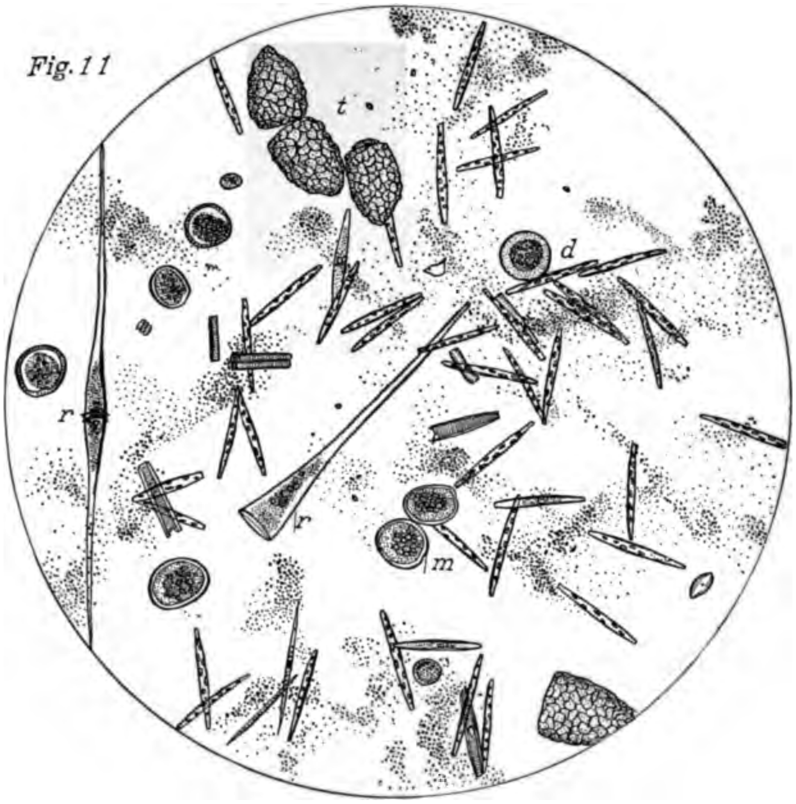

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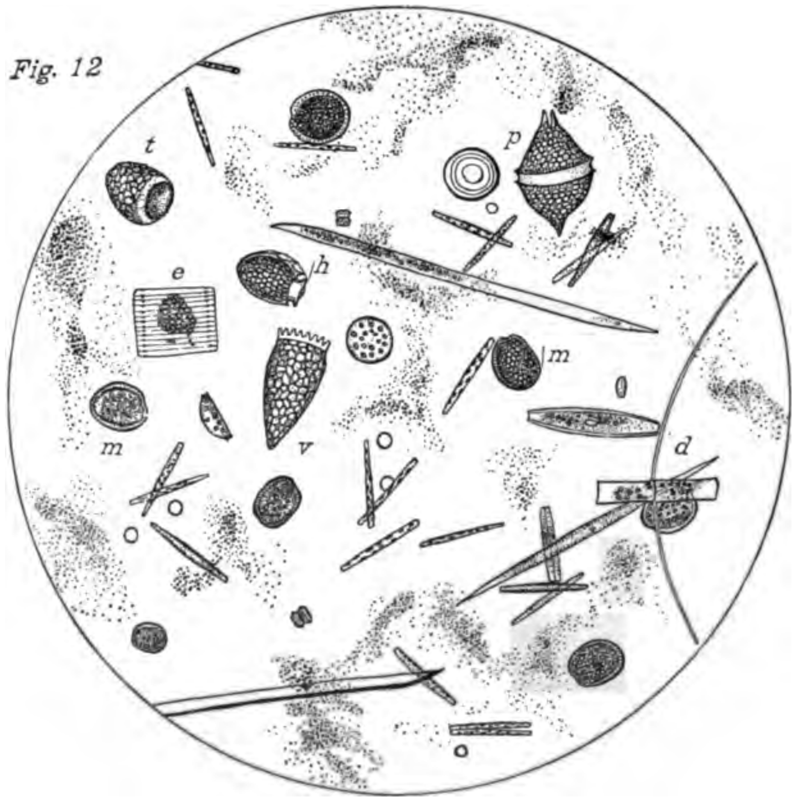

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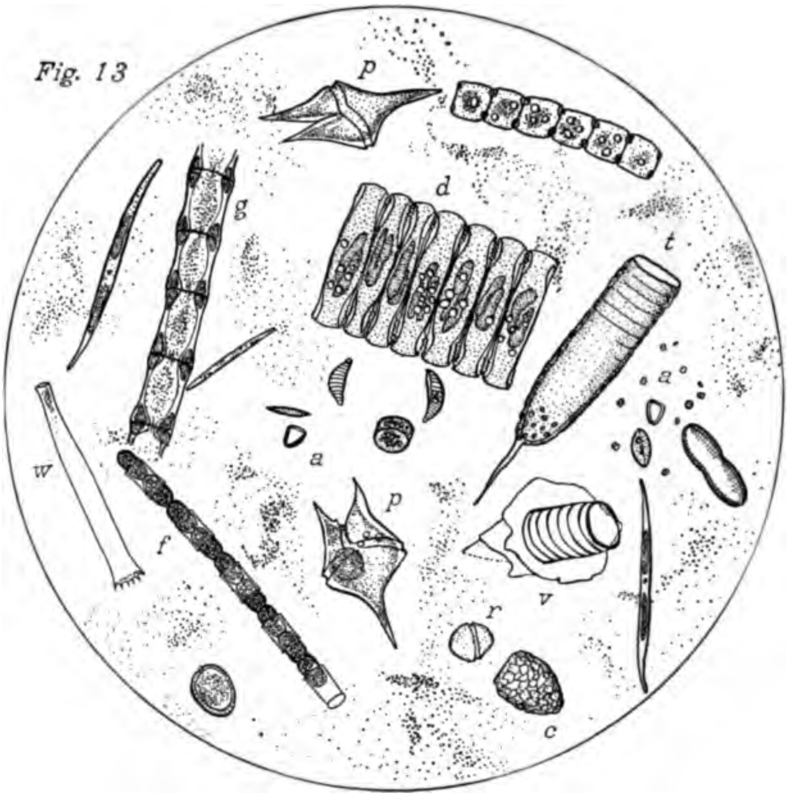

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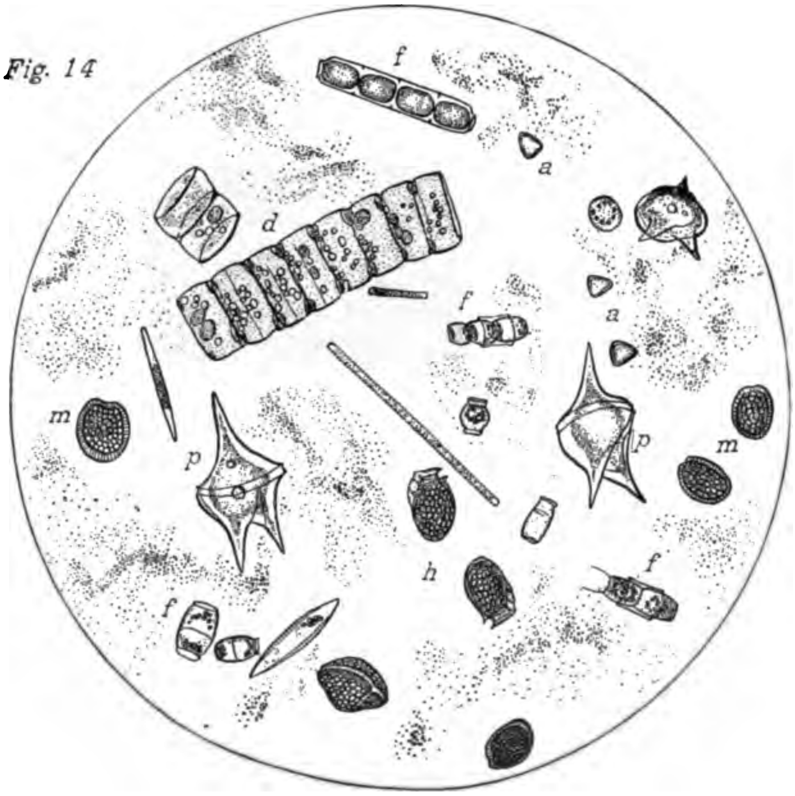

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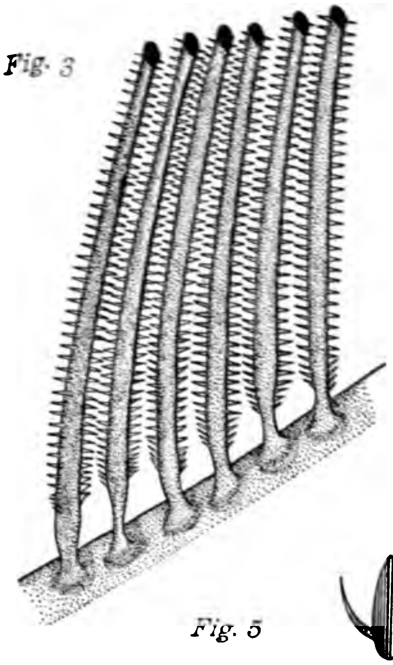

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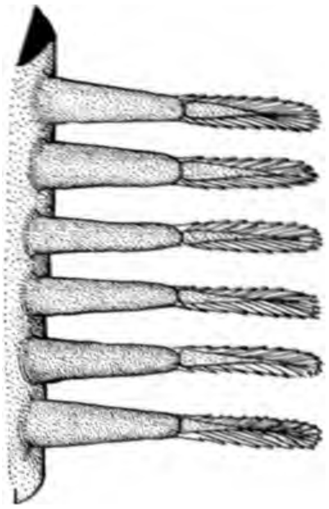

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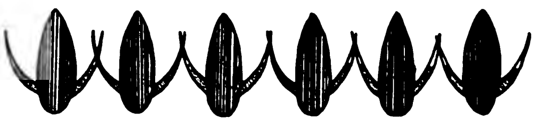

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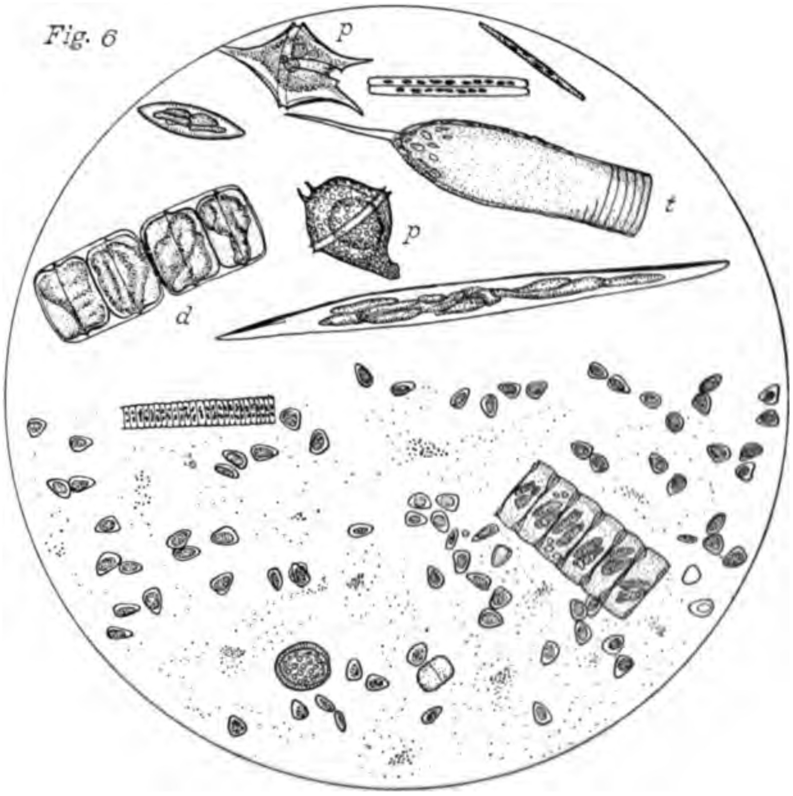

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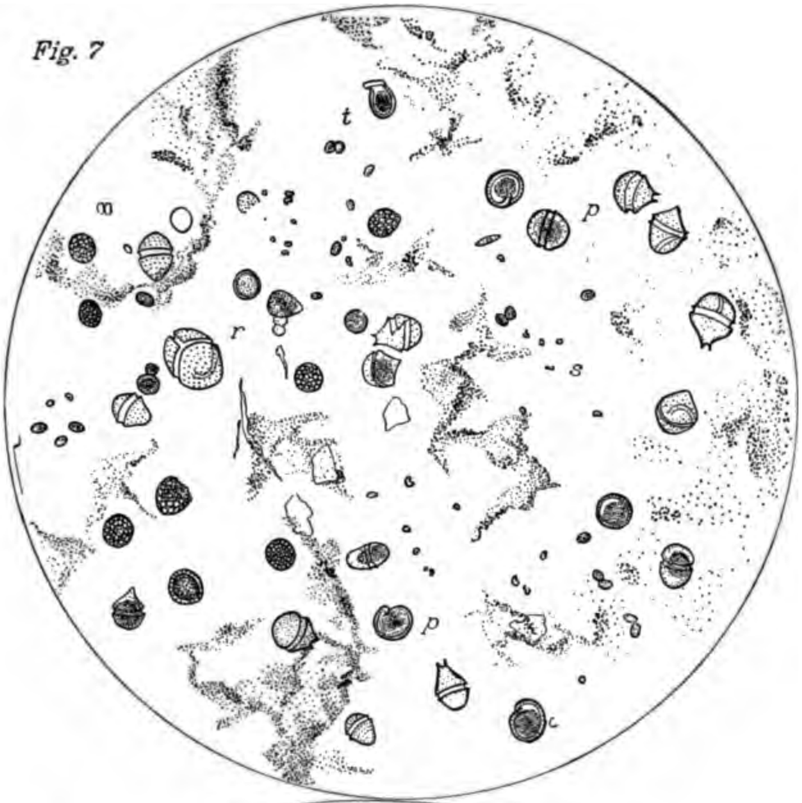

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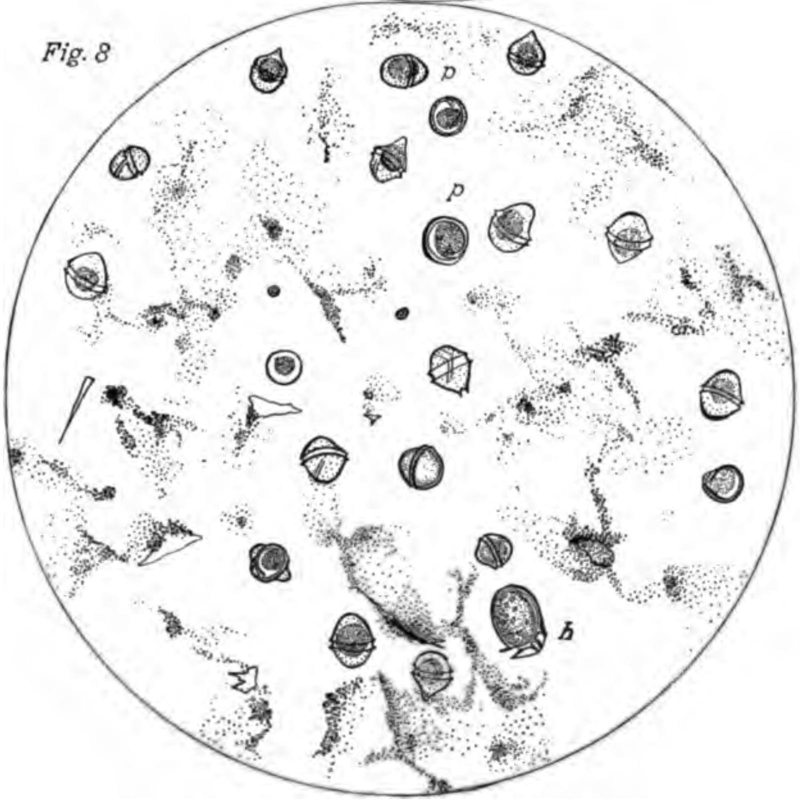

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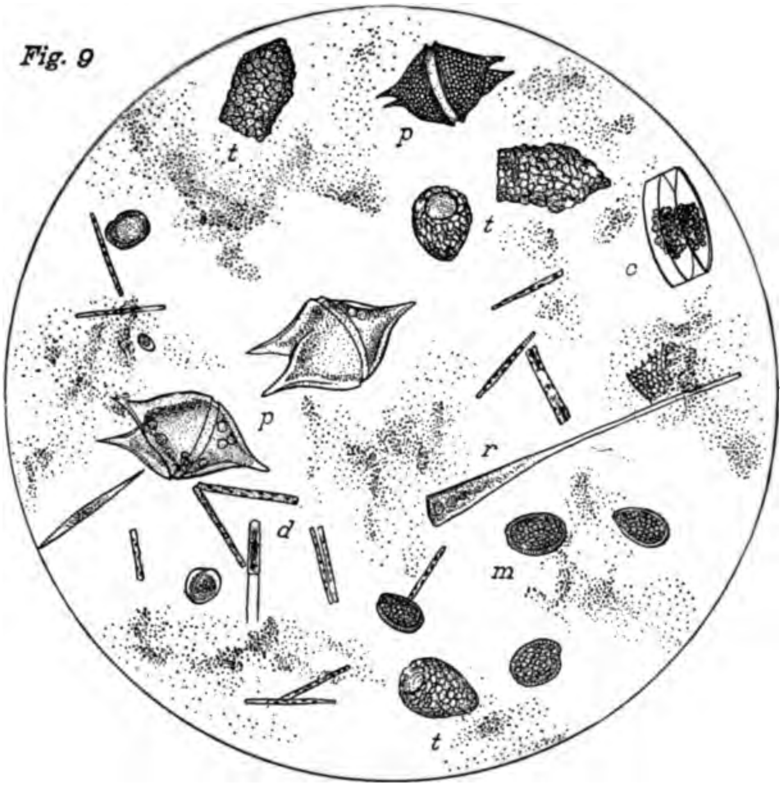

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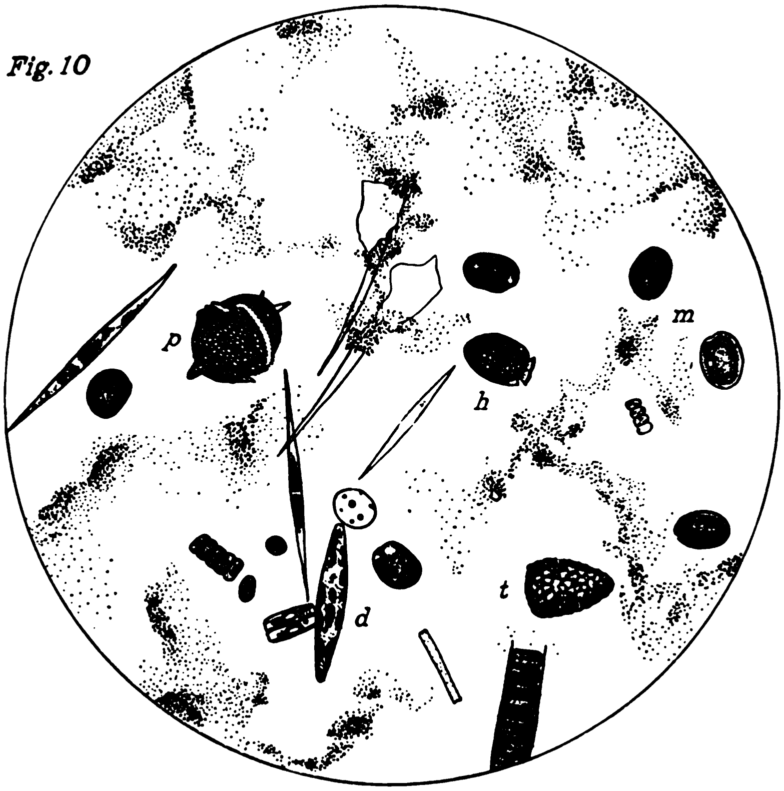

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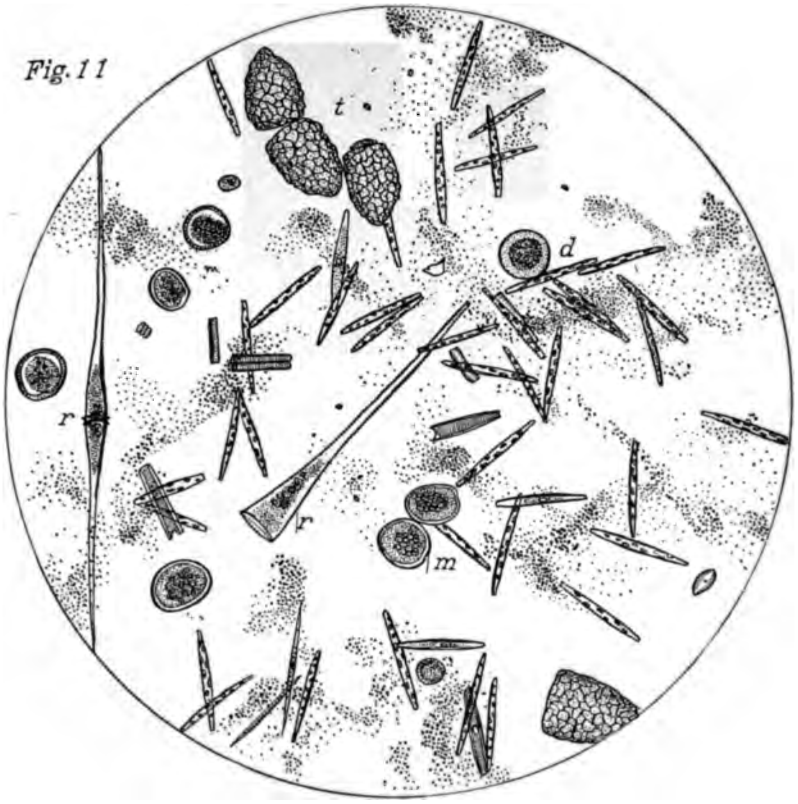
PLATE 5.

Fig. 11



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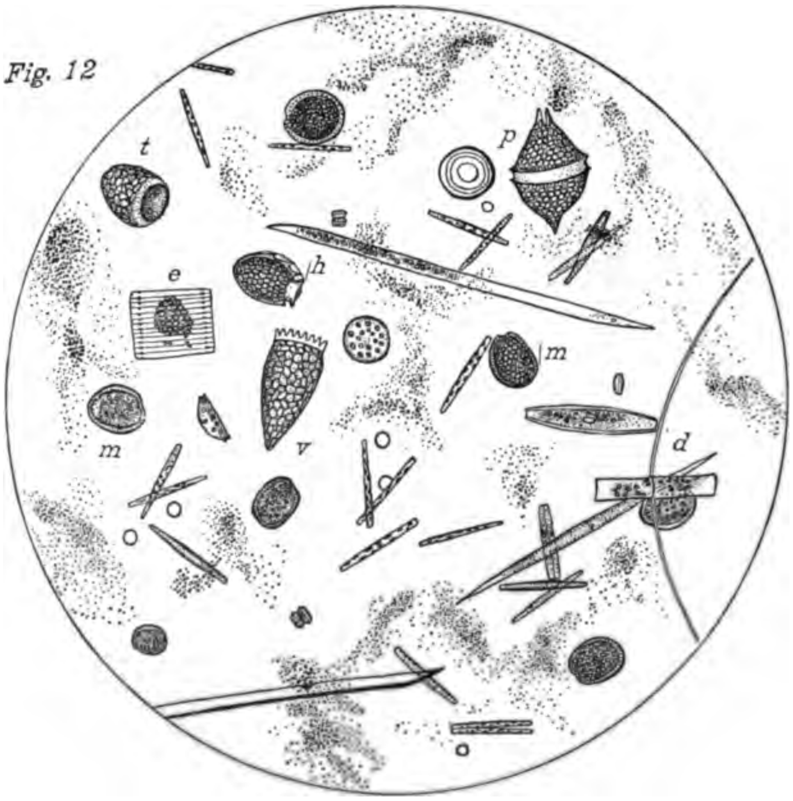

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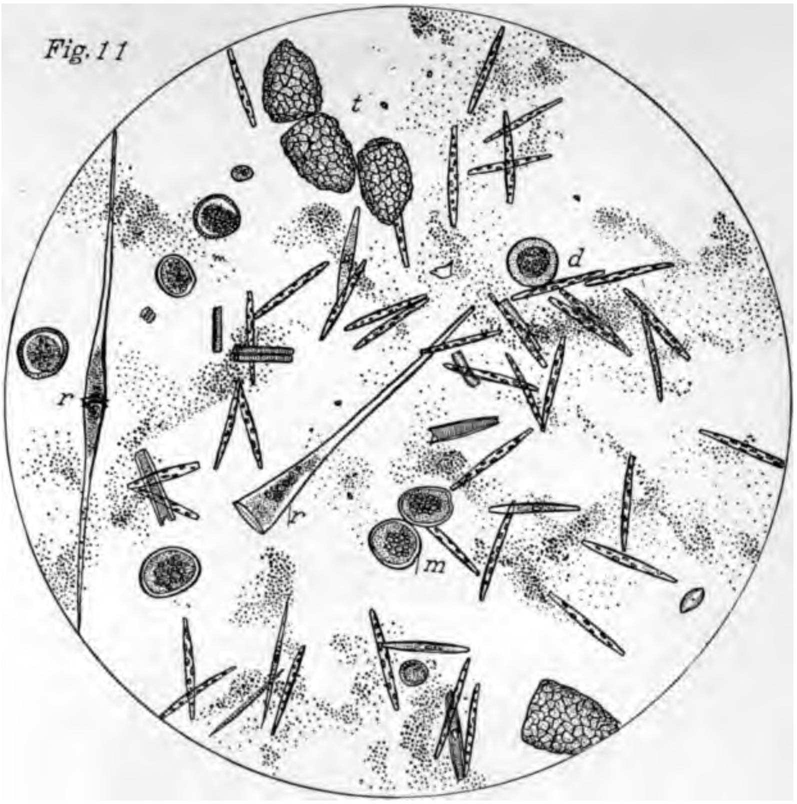

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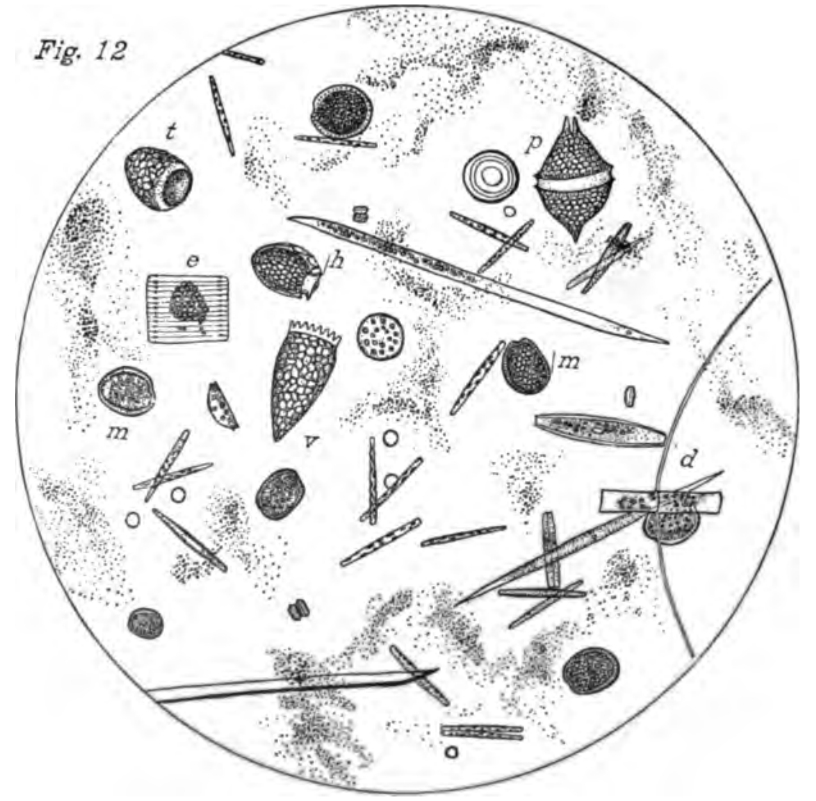

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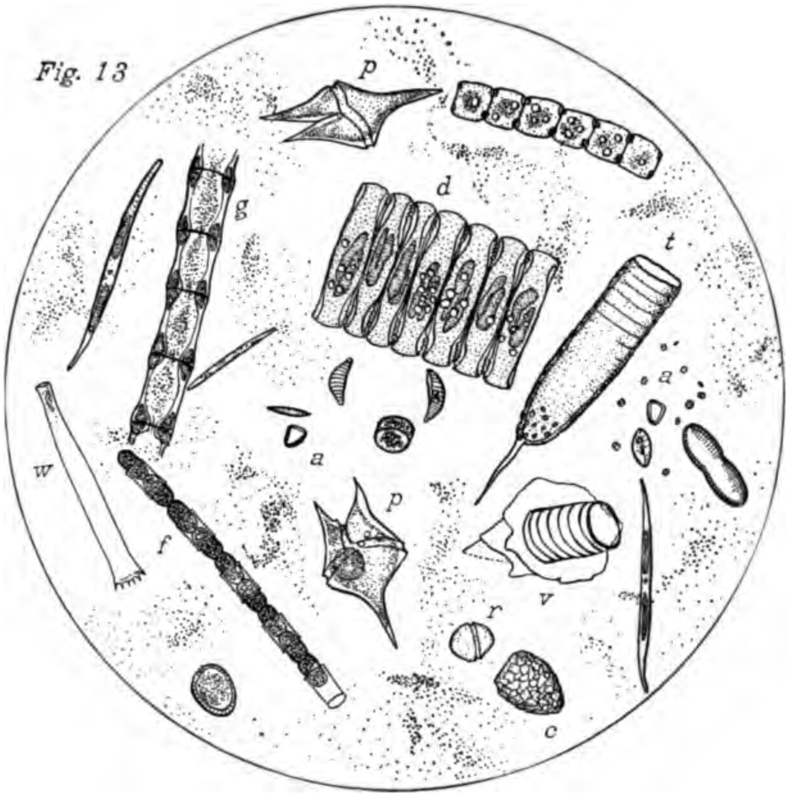

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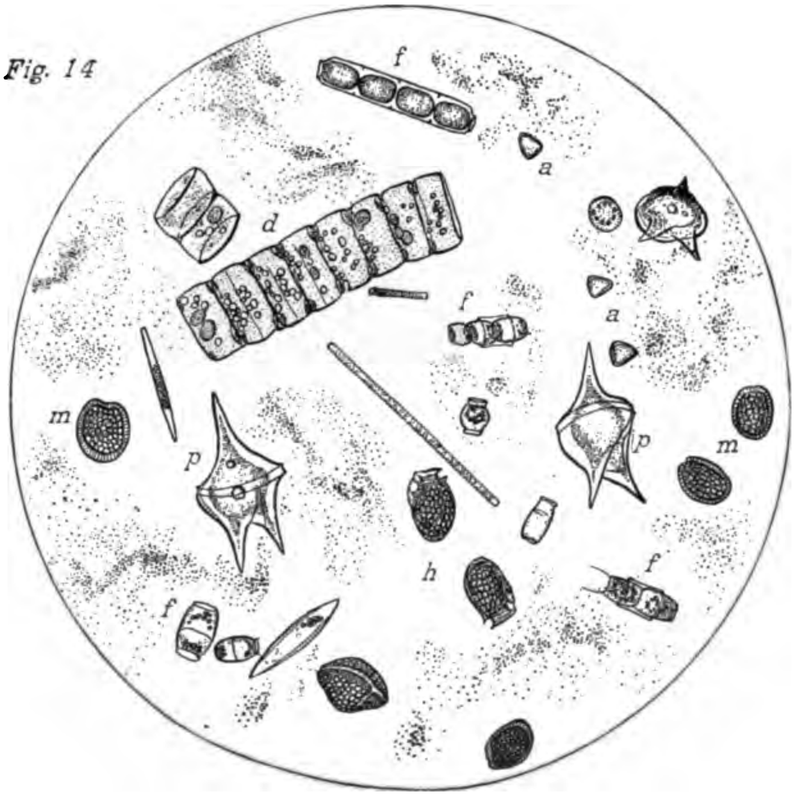

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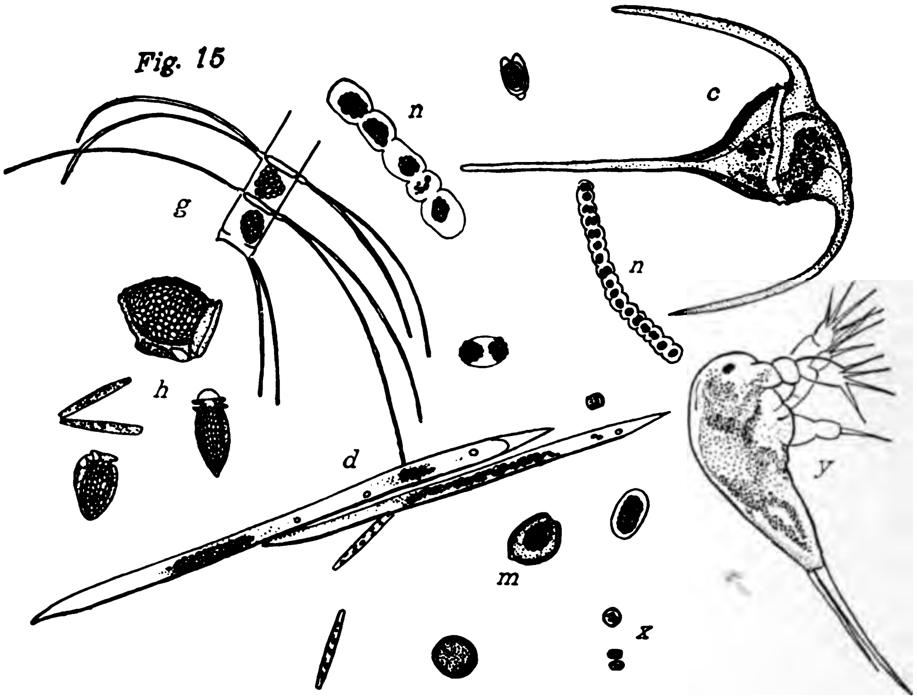

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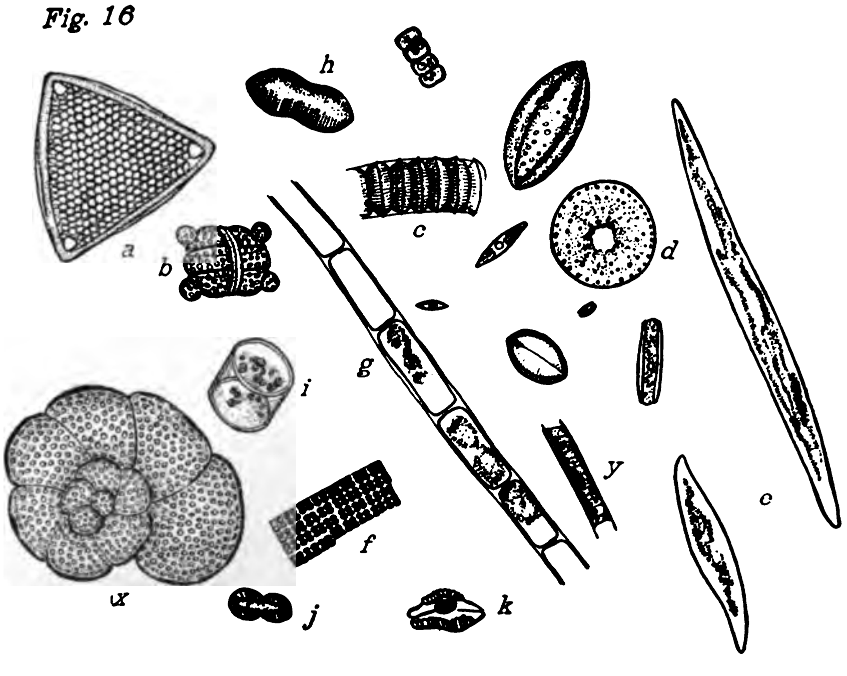

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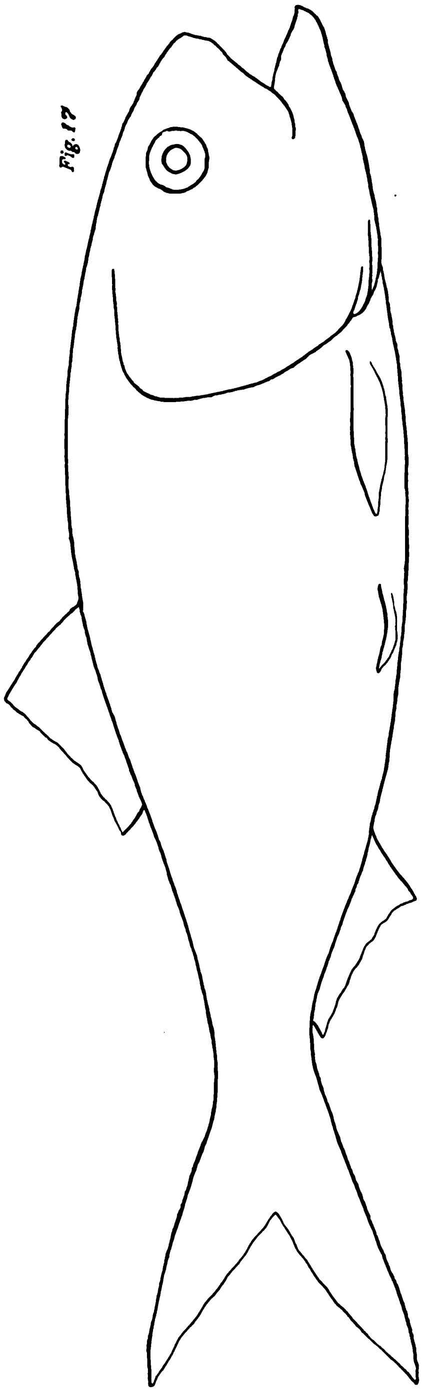
Fig. 17



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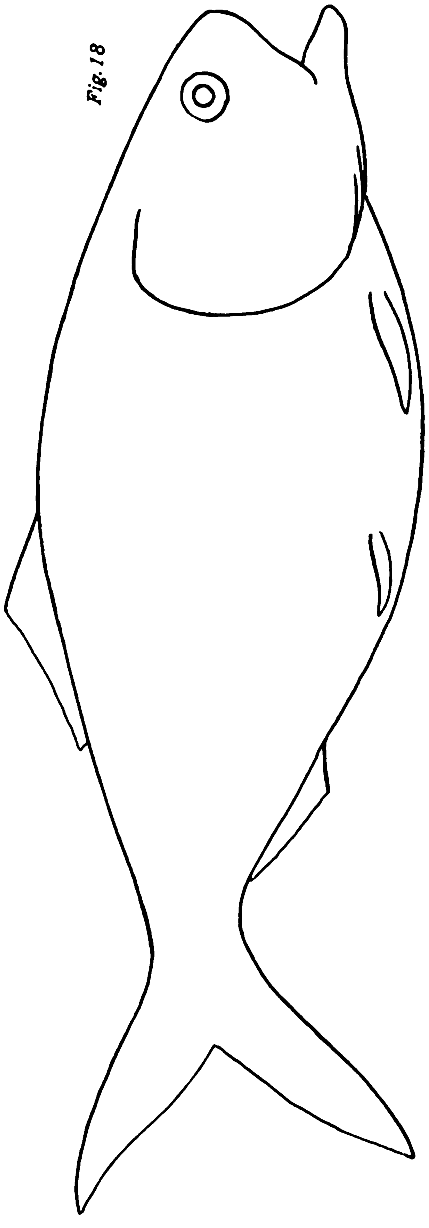

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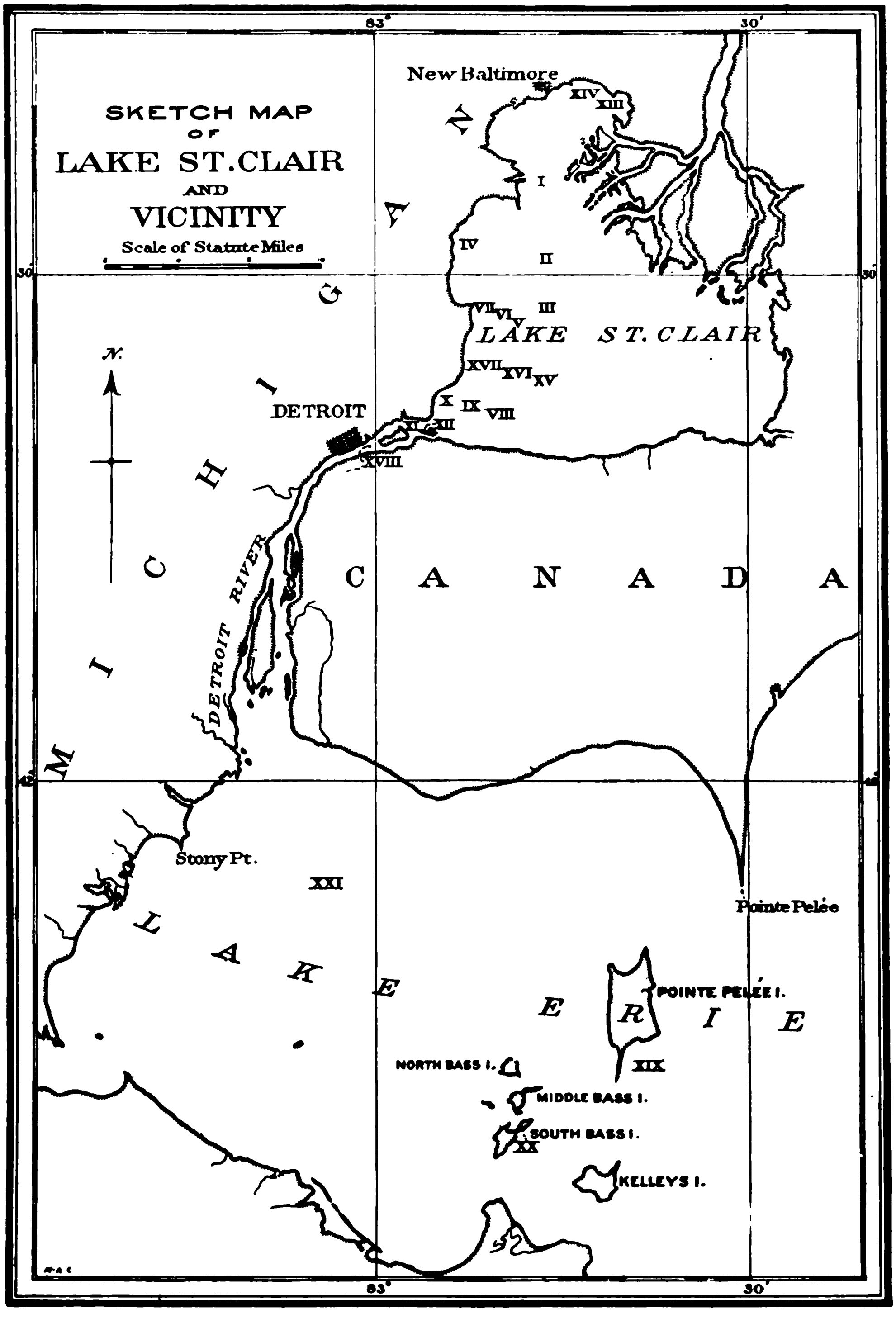
SKETCH MAP
OF
LAKE ST.CLAIR
AND
VICINITY
Scale of Statute Miles
N.
83°
30'
30
42
New Baltimore
XIV
XIII
I
II
IV
III
VII
VI
V
LAKE ST. CLAIR
XVII
XVI
XV
X
IX
VIII
XI
XII
XVIII
DETROIT
MICHIGAN
DETROIT RIVER
CANADA
Stony Pt.
XXI
Pointe Pelée
LAKE ERIE
POINTE PELÉE I.
NORTH BASS I.
XIX
MIDDLE BASS I.
SOUTH BASS I.
XX
KELLEYS I.

17.—SOME PLANKTON STUDIES IN THE GREAT LAKES.

BY JACOB E. REIGHARD,
Professor of Animal Morphology, University of Michigan.

The history of the whitefish industry of the Great Lakes is well known to the members of this conference. It is presumably the history of a diminishing production in spite of a very large annual outlay for artificial propagation. The enthusiasm with which the fish-culturists of twenty years back undertook the restocking of the Great Lakes was born of success in many similar enterprises. Trout and shad had been made to swarm in depleted waters. Similar results were, therefore, to be expected from the application of similar methods to the Great Lakes. These expectations have not been realized, and fish-culturists are casting about for an explanation.

On the one hand it is asserted that the expected increase in the yield of whitefish has not been realized because of the destructive methods of fishing. The ravages of the pound net are thought to be more than sufficient to wipe out the gain due to artificial propagation. It is said that if fishing methods were properly regulated the results of artificial breeding would at once make themselves felt, and that, while the planting of whitefish has not resulted in increasing the supply of adult fish, it has prevented any large reduction in that supply, so that many grounds, which now pay for the fishing, would have been utterly exhausted but for artificial propagation. The remedy for the present condition of things is believed to lie both in legislation controlling fishing methods and in a still greater extension of artificial propagation.

On the other hand it is claimed that if the artificial propagation of whitefish were successful it should result in an increasing yield in spite of existing methods of fishing. The remedy does not lie in restrictive legislation; it lies rather in greater effectiveness of methods of artificial propagation, and perhaps also in an increase of the annual output of artificially hatched fish.

The first view is held for the most part by fish-culturists, who favor restrictive legislation and increased facilities for artificial propagation. The second view is held for the most part by fishermen, many of whom are not yet convinced of the value of artificial propagation. When one who is neither fish-culturist nor fisherman attempts to discover the facts upon which the various opinions are based he very soon finds that there are but few recorded facts.

In order to know whether the number of whitefish is increasing or diminishing for any locality or for all localities it is necessary to have statistics extending over a term of years. Statements based on statistics which are taken in two years separated by an interval of five or ten years are nearly valueless for purposes of comparison, for the reason that such statistics do not and can not take into account the climatic conditions which make one year favorable and another year unfavorable. The fact that in the year 1880 the number of whitefish marketed was greater than in 1890 does not prove that the number of whitefish has diminished in this interval; it proves only that the number caught in 1890 was less than the number caught in 1880. This may have been due to a diminution in the number of fish, but it may also have been due to storms during the fishing season of 1890. Statistics, to be conclusive, should enable us to compare the average yield for the ten years 1870 to 1880 with the average yield for the years 1880 to 1890.

No such continuous series of statistics is in existence for the United States, so that the assertions concerning a diminishing yield of whitefish rest either on a comparison of the statistics of isolated years or on the statements of fishermen concerning certain localities.

If we inquire into the facts concerning the sufficiency of the present methods of artificial propagation we find that, so far as concerns the whitefish, there is no question as to the success of the earlier stages of the process. Several hundred million ova are taken annually and placed in the hatcheries, and of these usually from 80 to 90 per cent are hatched and placed in the waters of the Great Lakes, 165,000,000 in Lake Erie alone in 1888.*

This is very nearly all that is known about these young whitefish. About their food habits we know only that in captivity they eat certain species of crustacea.† Whether in their natural habitat they eat other animals in addition to these crustacea or in preference to them we do not know. It is uncertain at what age they begin to take food, or how much they require. We do not know their natural enemies. We do not know whether they thrive best in running water or in standing water; in shallow water or in deep water; whether at the surface or near the bottom. What changes of habitat or of food habits the fish undergo as they grow older is a still deeper mystery.

Our problem is to place young whitefish in the Great Lakes under such conditions that as large a number as possible of them shall grow into adult fish. It is clear that of one of the elements in this problem, namely, the whitefish, we know but little.

What, then, do we know of the other element of the problem, the Great Lakes themselves? Individual naturalists have made efforts from time to time to study one or another of the groups of animals living in the lakes. These efforts have been always circumscribed by the facilities at hand, by the time that could be devoted to the subject, by the small area examined, or by the small number of animals taken into account. Although much excellent work has resulted from these efforts, it remains true that there has been thus far no attempt to secure an accurate knowledge of all the conditions existing in any one locality, and no attempt to study exhaustively a single group of the animals and plants of the lakes. We are still at the beginning, so far as concerns a knowledge of life conditions in these lakes—the conditions with which we surround our young whitefish. If we could assume that the conditions are uniform over the whole area of the Great Lakes, then, since the young whitefish are native to these lakes, it might be a safe conclusion that they will find the conditions in one locality as well for them as in another. But there are no facts which support the view that the conditions are uniform over the lakes.

We are thus in the position of bringing together under unknown conditions two things, both of unknown character, and we expect as a result to get a third thing, marketable whitefish. Should we not pursue our object more intelligently by first determining the characteristics of the materials with which we have to work? It was with this object in view that the Michigan Fish Commission, in the summer of 1893, established a scientific laboratory on Lake St. Clair. This lake is readily accessible from the Detroit hatchery at the season when whitefish are planted. Whitefish are caught in certain parts of the lake in considerable numbers in the spawning season, so that it is probable that spawning-grounds of this fish are found along the west shore of the lake near its outlet. In establishing a laboratory on the lake the Michigan Fish Commission hoped, therefore, to accomplish two things:

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* This appears by adding the number of fry planted in 1888 by the U. S. Commission and by the commissions of Canada, Michigan, New York, Ohio, and Pennsylvania, as shown in the reports of those commissions.

† Forbes, S. A., The First Food of the Common Whitefish. Bulletin No. 6, Illinois State Laboratory of Natural History, May, 1882.

(1) To study carefully, and in the broadest possible way, the life of the lake. After examining the physical characteristics of the lake, such as the color, transparency, and chemistry of the water, such a study should include a determination of the kinds of animals and plants in the lake. Every species should be sought out, carefully described and figured, and a specimen of it preserved. Then the habits of each species should be known, its habitat, its food, its enemies, and its parasites. The numbers of animals and plants of each species in a given volume of water should be determined, and the variations in these numbers in different parts of the lake and at different seasons of the year. Such a collection of data would form a complete picture of the biology of the lake.

(2) It was hoped that young whitefish might be captured in the lake by suitably arranged nets and that it might thus be possible to determine the food habits of the young fish and the other conditions under which they are found in nature.

Should both these objects be accomplished we should be in a position to determine where in the Great Lakes are to be found the conditions favorable to the whitefish fry.

The materials collected have not been all worked up at this time, so that it is possible to give only a brief survey of the plan of work together with some of the more immediate results.

The laboratory was located at New Baltimore, near the head of Anchor Bay, which is the northeastern portion of Lake St. Clair. Here the second story of a large warehouse, situated on a dock, was transformed, by the use of temporary sheathing, into a commodious laboratory room about 20 by 40 feet. There were four large and very rigid laboratory tables, designed especially for their portability and intended each for two workers. The vacant places on the walls were filled with temporary shelves, and two large work tables were provided for general purposes. At one of the windows was placed a table arranged to hold a dozen small aquaria, to which running water was supplied from a tank outside the building. On the wharf without was erected a temporary shed which sheltered three large aquaria supplied with water from a special tank. In these aquaria the largest fish of the lakes could be kept under observation.

The laboratory was supplied with a sail and row boat. For more extended trips and for use with the heavier collecting apparatus there was a small steamer, the *Ben Hur*, of Detroit, a boat of about 10 tons burden, and with a very roomy cabin. She was found to serve every purpose admirably.

A considerable collection of pertinent literature as well as microscopes and the other usual laboratory apparatus were loaned by the University of Michigan. A liberal supply of the usual glassware and reagents and of the minor apparatus was provided by the fish commission. The collecting apparatus included the usual hand nets, tow nets, and dredges. Besides these there were some forms of nets not in common use. The ordinary form of deep-sea dredge was found to slip over the hard clay bottom or over the thick matting of characeæ which covers this bottom, so that it usually came up empty. In its place was used a dredge made as follows: An iron band 2 inches broad, ⅜ of an inch thick, and 4 feet 6 inches long, is cut along one edge into a row of triangular teeth, each an inch broad and an inch high. These teeth are sharpened and bent so as to form an angle of about 15 degrees with the rest of the band, which is provided with holes into which a net may be laced. The band is then bent on the broad side into the form of an equilateral triangle, with the teeth inclined outward. To each angle is welded a stout ring for the dredge rope, and also an iron rod, 2½ feet long, which projects at right angles to the plane of the triangle and from the edge of the band opposite the teeth. A flat net of inch mesh is suspended from the triangle, and its bottom is lined for about a foot with coarse cotton cloth. The whole net frame has thus the form of a triangular prism and when dragged along the bottom always rests upon one side, so that the teeth at the edge of the frame act with great effectiveness in loosening objects imbedded in the hard clay bottom. This net is modeled from one exhibited among the apparatus of the plankton expedition in the German University exhibit at the World's Fair.

Another piece of apparatus of great value is the net designed by Prof. E. A. Birge for collecting cladocera, and described in Trans. Wis. Acad., vol. VIII, 1891. It is indispensable on weedy bottom or shores.

The ordinary tow net when weighted to be used on the bottom is apt either to run at an unknown distance from the bottom, or, if it reaches the bottom, to foul in the weeds or fill with mud and sand. We therefore made use of a tow net supported on four flat iron runners which are welded to the iron net ring. These runners extend for about 30 inches at right angles to the plane of net ring and are then bent toward one another and riveted together at a point opposite the center of the net ring and 3 feet from it. The net thus hangs within the frame formed by the runners, and its mouth is held about 2 inches from the bottom. This proved an excellent device for collecting bottom forms free from weeds or mud.

For quantitative work we used a vertical net which is more fully described in another place.

Six persons worked in the laboratory from July 15 to September 15. They were—

Prof. J. E. Reighard, director; quantitative work, crustacea, and vertebrates.

Dr. H. B. Ward, associate professor of biology, University of Nebraska, Lincoln, Nebr.; worms.

Mr. Frank Smith, instructor in zoölogy, University of Illinois, Champaign, Ill.; protozoa and mollusca.

Dr. Robert Wolcott, Ann Arbor, Mich.; insecta and hydrachnida.

Mr. H. S. Jennings, assistant in animal morphology, University of Michigan; rotifera, sponges, and bryozoa.

Mr. A. J. Pieters, assistant in botany, University of Michigan; plants.

Each had charge of that portion of the subject set opposite his name. These gentlemen worked enthusiastically, and without compensation, in the interest of science, so that whatever results have been reached are largely due to their unselfish devotion.

Two employés of the fish commission, Mr. Dwight Lydell and Mr. Jesse Marks, rendered valuable service in collecting, fishing, and otherwise furthering the interests of the laboratory.

The first six weeks were spent in qualitative work, that is in making a list of the animals and plants of the lake, in noting the way in which they were associated, their habits, and in preserving specimens, drawings, and records of observations. Every morning, and frequently again in the afternoon, a man was sent out into the bay, with the different sorts of nets. With the tow nets were obtained the smaller animals and plants floating in the water, at the surface, in mid-water and near the bottom. The forms attached to the bottom or concealed among the water plants were collected by means of the toothed dredge and by the Birge net. Collections were also made near the shore with the same apparatus. All the materials were brought to the laboratory and were ready for examination upon the arrival of the laboratory force. Each worker then sorted out from the collection the materials belonging to him. This method of working was kept up until it was felt that all the inhabitants of the lake, except possibly a few rare or occasional ones, had become familiar. The living specimens were studied in all cases and material was preserved for future use. Final identifications were attempted only in the cases where the original literature in the laboratory was ample for the purpose.

At the same time that collections were being made of the smaller inhabitants of the lake, gill nets were set every day for the capture of fish, while other fish were purchased from the fyke-net fishermen who landed their catch at the laboratory dock. The stomachs of several hundred of these fish were examined and the contents preserved, with the purpose of determining the food habits of the fish. At the same time the fish were systematically searched for parasites, and many important biological data were collected concerning the parasites. A more detailed report on these parasites is in preparation by Dr. Ward.[*]

In order to make a continuous and systematic record of the forms examined, use was made of blanks in which each person entered the forms observed by him. The blanks were of two kinds, one intended to give the important data concerning the individual animals and plants and the other intended to show how these animals and plants are associated under different conditions. The following is a sample of what may be called the individual blank:

NAME Sida[†] crystallina O. F. M.

No. —DRAWING ——SPECIMEN ——NOTES 117, 124.

LOCALITY middle of Anchor Bay

HABITAT

PELAGIC		DEPTH					
LITTORAL		"		BOTTOM		VEGETATION	
BOTTOM	x	"	13 ft.	"	Clay	"	Characeæ.

FOOD dinobryon; diatoms; shells of both found in excreta.

ABUNDANCE moderate.

BREEDING HABITS { ♀♀ with embryos & larvae in brood sac.
♂♂ not found.

REMARKS greenish transparent color is noteworthy. The grinding surfaces of mandibles suggest the crushing of diatoms.

DATE Aug 11, 1893 **HOUR** 7 a. m. **SIGNT.** J. E. Reighard.

This blank gives the results of the observations of a single day on a single species of *Sida*, the name of which appears at the top of the card. Whenever this species was observed under different circumstances a new card was made for it. By sorting all the cards referring to a single species one has at hand in condensed form all the facts recorded concerning it.

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[*] This report will appear as a bulletin of the Michigan Fish Commission.

[†] The words in this light-face type were added with the pen.

These blanks did not take the place of note books but were meant merely to condense and systematize the records made in the note books.

The other form of blank may be called the *collective* blank. A sample of it appears below. It is a modification of a form used at Mr. Agassiz's Newport laboratory.

No. ________ RECORD OF COLLECTIONS.

Made at ________________
Tow at ________ *Dredged at* ________ *ft. on* ________ *bottom*
With ________ *net, along* ________ *shore* ________
Jan. Feb. Mar. Apr. May. June. July. Aug. Sept. Oct. Nov. Dec. ________ A.M.
1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20,
21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31. 189____ ________ P.M.
Water: ________, *Wind:* ________, *Sky:* ________
Temp. air: ________, *Temp. water:* ________, *Barometer:* ________
Remarks: ________________

________________ *Observer.*

Name.	Very many.	Many.	Scarce.	Name.	Very many.	Many.	Scarce.

Blanks of this form were passed from one worker to another, and each person entered in them the forms which he had found as taken in a certain net at a certain time and in a certain location. The blanks thus serve to show the way in which the forms are associated and their relative numbers under different conditions at different times. To properly fill one of these blanks was usually the work of six observers for the greater part of a day.

For the records of parasites there was a third form of blank, designed by Dr. Ward and shown in the accompanying copy. It is intended to bring together certain data concerning the animal infected and the numbers and kinds of parasites.

No.
Name ________________
Size ________ *Age* ________
Locality ________________
Examined by ________________ *189*__

PARASITES FOUND.

Name.	No.	Organ inhabited.	Condition.	Remarks.

Notes:

A similar record was kept of the contents of the fish stomachs, but no special blank was used for this purpose. It is desirable to use such a blank.

Reports are now in preparation by the various members of the laboratory staff, and as these are soon to be published as bulletins of the Michigan Fish Commission, detailed statements will be reserved for such publication. The following statements as to the biological conditions existing in the lake may prove of interest.

As to the lake itself, it has nearly the form of an equilateral triangle with rounded angles and with sides, each of which measures 25 to 30 miles. The southern and shortest side of the triangle runs nearly east and west, its western side inclines toward the east as it extends northward, while the third and longest side looks directly toward the northeast, and may be called the northeastern shore.

In the middle of this northeastern shore the lake receives the waters of the St. Clair River, which carries the overflow of the three upper lakes. At its entrance into Lake St. Clair the river breaks up into several channels, each of which again divides once or twice, so that the water of the river enters the lake through nine well-defined mouths of various sizes. These mouths are scattered for a distance of 20 miles along the northeast shore and discharge their waters into the lake at a considerable velocity. Between the channels which diverge from the main river to these mouths is swampy, shifting ground, which forms an enormous delta overgrown with rushes and covered usually by a foot or more of water. These are the celebrated St. Clair flats. The banks of the channels only are usually formed of moderately firm ground, and it is upon them that numerous summer residences and hotels have been built.

The northwest corner of the triangle receives the greater part of the discharge of the northern fork of the river (North Channel) and is partly cut off by a projecting point of the west shore, so that there is formed a bay, Anchor Bay, upon which is situated the town of New Baltimore. From the southwest corner of the triangle the Detroit River leaves the lake and flows at first toward the west. The water poured into the triangular lake by numerous mouths along nearly the whole of one side, thus converges to the angle opposite this side, where it flows out. The lake is but little more than an enormous expansion of the river, so that almost everywhere there is a current, usually slight, but in some places near the mouths of channels reaching a velocity of 3 or 4 miles an hour. The lake is shallow. Over a large central area the bottom is quite level and the water has a nearly uniform depth of 20 feet. From this central area the depth diminishes toward the shores in every direction. The shores, so far as we examined them, are made by a clay bluff, which varies in height from 1 or 2 feet to perhaps 10 or 20 feet. Mixed with the blue clay which forms the bluff, there is more or less gravel or sand, and the action of the waves has in many places washed this free from the clay and left it in the form of little stretches of gravelly or sandy beach. The bottom of the lake is everywhere composed of the same mixture of blue clay with sand or gravel. On the bottom also the finer clay particles have been washed away from the superficial layer of the bottom, so that there is left everywhere a thin layer of fine sand or gravel which separates the hard clay bottom from the overlying water. This layer of sand is in some places so fine that it is known popularly as mud.

The water of the lake is not clear. No measure of its transparency has yet been made, but it lacks the great transparency of the water of the northern lakes. The shallow water near the shore is always much roiled by even moderate waves, apparently by reason of fine particles of clay suspended in it. A zone of this roiled water extends for perhaps a quarter of a mile from the shore and disappears only in very quiet weather. The temperature of the water in August and September was 65° or 66° F. There was but little difference between the bottom and top temperatures. In the deepest water the difference was about 1°.

The entire bottom of the lake is clothed with vegetation. The plants are, for the most part, stoneworts of several kinds. There are also some flowering plants and algæ, all of them enumerated in the report of the botanist.* Together they make a dense green carpet which appears to vary in thickness from 2 or 3 to 6 or 8 inches. It harbors a rich bottom fauna and should be good pasture ground for such bottom-feeding fish as the carp.

As for the smaller animals and plants found in the lake the following summary is sufficient. The net drawn at the surface showed usually 8 or 10 species of protozoa, about 15 species of pelagic rotifers, 5 or 6 species of crustacea (cladocera and copepoda), and about 20 species of diatoms and other algæ. A few fish larvæ of unknown species were taken, and occasionally there occurred a hydra, some insect larvæ or pupa skins, a snail or a worm, all evidently wanderers from the bottom. Algæ, rotifers, cladocera, copepoda, and protozoa make up nearly the whole of the surface life.

If the net be run in midwater or near the bottom, but in such a way as not to stir up the bottom vegetation, very nearly the same result is obtained. The algæ, the protozoa, and the rotifers are, with few exceptions, of the same species as those living in the surface water. A few ostracoda are now added to the crustacea taken, and occasionally an amphipod, both probably caught by the net as they left, for a moment, their hiding-place among the plants of the bottom. An occasional annelid also appears.

If a dredge be used which stirs up the water plants and harrows up the bottom the result is far different. All the forms previously noted are of course brought up, but in addition there are many that are peculiar to the bottom. The larger plants growing on the bottom in deep water have already been mentioned. They are mostly characeæ, with some elodea, naias, and valisneria. A larger list of algæ is found and includes several filamentous forms. The number of protozoa is greater and the list of rotifers grows from 15 to about 60. It includes many fixed forms. Among the crustacea there is now a preponderance of ostracoda and amphipoda, though the other groups are still well represented. The dredge brings up several sorts of animals never found in the free water above. First are the mollusks, mussels which are partly imbedded in the bottom, and many species of snails which are crawling about over the plants on the bottom. Secondly, many sorts of insect larvæ, especially those of the dragon-flies and may-flies are dragged from their hiding-places on the bottom. A third sort of animal found only in the bottom dredge are the water spiders or hydrachnids. There are probably 36 sorts of these voracious little cannibals, and they are very numerous in individuals. In the fourth place, many worms are found, some nematodes, many small oligochæta, and a few leeches. A few hydras and an occasional sponge or bryozoon complete the list of the bottom fauna. Its striking elements are the mollusca, the insect larvæ, the water spiders, the worms, the amphipod and ostracod crustacea.

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*To be published in the Botanical Gazette and also as a bulletin of the Michigan Fish Commission.

The fish which occur in the lake are the usual and well-known inhabitants of these waters and need not be enumerated here. A few frogs and turtles and many gulls and terns complete the list of the fauna. The roily water of the lake, especially near the shore, is probably not favorable to the existence of many species of protozoa, sponges, bryozoa, or littoral crustacea. The total number of species found in the lake can not be stated until the collections have been more exhaustively studied. So far as studied the collections show species distributed as follows:

Plants:	
Phanerogams (17 of these are littoral, 1 to 6 feet of water)	52
Of these, but 3 (*Elodea*, *Naias*, and *Valisneria*) occur on the bottom usually in deep water; the others are in shallow water (5 to 12 feet) and reach the surface or extend above it.	
Characeæ	5
Algæ, filamentous: 2 (*Vaucheria*, *Cladophora*) on the bottom in deep water; 2 (*Spyrogyræ*) floating in shallow water	4
Algæ, other: 31 pelagic; 65 attached to or associated with larger plants	96
	157
Animals:	
Protozoa	14
Sponges	1
Hydroids (Hydra)	2
Rotifers: pelagic 18, on bottom in deep water 42, near shore 57	117
Bryozoa	1
Annelida, estimated at about	15
Platyhelminthes and Nemathelminthes (including parasites)· 166 vials of material were preserved; the number of species cannot be stated.	
Crustacea, at least	36
Hydrachnids	36
Insects and insect larvæ	75
Mollusca	35
Fishes: Ganoids, 3; Teleosts, 22	25

The total is not less than 500 species and may reach 600.

Many of the species above recorded are now known to be new, and the study of the collection will doubtless discover a still larger number of undescribed species. The new forms are, for the most part, among the rotifers, hydrachnids, and parasitic worms, though there are a few new crustacea, annelids, and protozoa.

In addition to the work which has been done in the identification of these forms by the laboratory staff, the following gentlemen have undertaken to work up the groups set opposite their names.

Dr. R. Blanchard, Paris, France; the leeches.

Dr. E. A. Birge, University of Wisconsin; the cladocera.

Dr. G. Eisen, San Francisco; the oligochæta.

Prof. C. D. Marsh, Ripon, Wis.; copepoda.

Dr. W. McM. Woodworth, Harvard College; the turbellaria.

Aid has also been received in the identification of the mollusca from Mr. Bryant Walker, of Detroit; in the characeæ from Dr. T. F. Allen, of New York City; and in the desmidaceæ and unicellular algæ from Mr. L. N. Johnson of the botanical department of Michigan University.

After six weeks spent in determining the composition of the lake fauna and flora, the attention of the laboratory staff was turned toward the question of the distribution of these forms and toward measurements of the total volume of living forms found in a given volume of water and of the numbers of each species in a given volume of water. For this purpose twenty-one stations were selected. Fifteen of these were in Lake St. Clair. Since the time was limited, these fifteen stations were located on the American half of the lake and were more numerous in the neighborhood of the fishing-grounds. Their distribution is shown on the accompanying chart. It will be noticed that while they are not scattered over the entire lake, they represent all the conditions of bottom, shore, and depth that are to be found in the lake. Any conclusions concerning them probably hold for the entire lake. Three stations were located near the head of the Detroit River, while for the purpose of comparison three others were located in the western end of Lake Erie.

At each station the various forms of nets described were used and the collections made were preserved. Their study will determine the distribution of the animals and plants.

An attempt was also made to measure at each station the quantity of animals and plants floating free in the water under each square meter of surface. No methods have yet been devised for determining the quantity of the animals or plants that are attached to the bottom or that live upon it. Measurements are, therefore, to be made only upon those forms that are found floating free in the water. There is reason to believe that whitefish fry (and probably the fry of many other young fish) feed for a time upon minute animals (crustacea) floating free in the water. If this is true, it becomes at once a question of great practical importance to know where these crustacea are to be found in greatest numbers, so that the whitefish fry may be planted in such localities. Such measurements have also a very high scientific interest.

Quantitative determinations of the living forms in the water have not been previously undertaken in this country and its methods are almost unknown among us. They have been conducted on a large scale by Prof. Victor Hensen, of the University of Kiel, in Germany. Hensen has examined the waters of the North Sea and more recently those of the Atlantic Ocean, and has perfected very ingenious apparatus for the purpose. Apstein,* a pupil of Hensen, has adapted this apparatus for use in fresh water, and has made a careful study of several fresh-water lakes in the neighborhood of Kiel.

As it was found necessary for work in the Great Lakes to modify the apparatus and methods used by Hensen and Apstein, I give here a somewhat detailed account of our procedure.

The name *plankton* has been given by Hensen to all those animals and plants which are found floating free in the water and subjected to the action of the waves, currents, or tides. Thus adult fish do not belong to the plankton, since they are able to move about independently of waves or currents. Fish eggs and young fish fry are

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* Das Plankton des Süsswassers und seine quantitative Bestimmung. Schriften d. Naturw. Ver. f. Schleswig-Holstein. Bd. IX. Hft. 2. 1892.

Quantitative Plankton-Studien in Süsswasser, Biologisches Centralblatt. Bd. XII. 1892.

PLATE 10.

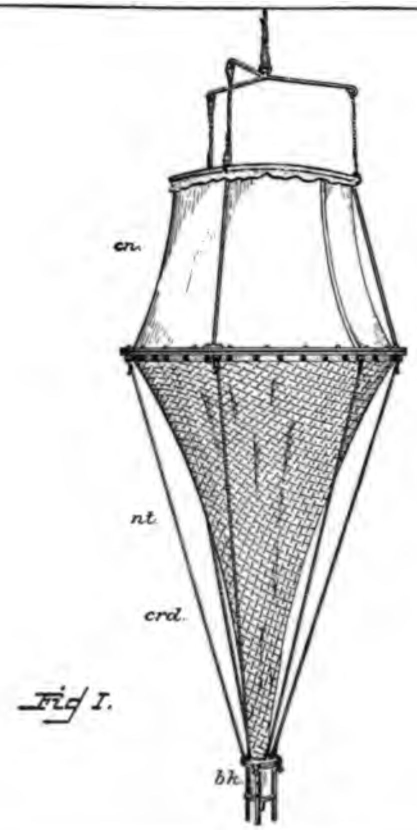

Fig I.

Fig 2.

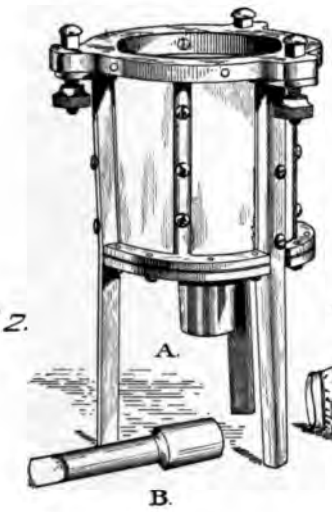

Fig 3.

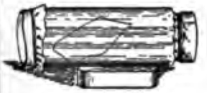

Fig. 1. Vertical net, ready for use. When the net is out of the water its mathematical form is somewhat distorted by its own weight.
Fig. 2. The bucket removed from the net and shown on a larger scale. The bucket is shown at A ; the plug, removed from the inside, is shown at B.
Fig. 3. One of the tubes containing plankton.

reckoned as a part of the plankton. The constitution of the plankton varies, since occasionally forms which belong on the shore or bottom wander into the free water and become a part of the plankton.

In order to measure the quantity of plankton contained in a lake, or in any portion of a lake, it is necessary to strain a certain volume of the water through a fine net and to weigh or measure the material thus obtained. The volume of the water taken should be a representative one; that is, it should consist of water taken at all depths. In other words, it is necessary to strain a vertical column of water extending from the bottom to the surface. The only practical way of doing this seems to be to draw a fine net through the water vertically from the bottom to the surface. Such a net strains a column of water of known height and with a base equal in area to the net opening. It collects at a single haul all the plankton under an area of lake surface equal to the area of the net opening, and by measuring the plankton thus taken under a small area it is possible to calculate the total plankton contained in the lake, or under any desired area of the lake.

The net used for this purpose is shown in the accompanying plate, fig. 1. The upper part of the net consists of a truncated canvas cone (*cn*) supported on an iron framework. This cone is about 40 cm. high; the smaller end has a diameter of 40 cm. and the larger end a diameter of 60 cm. It is impervious to water and serves two purposes. When the net is let to the bottom it prevents the mud which may be upon the bottom from getting into the net, and when the net is being drawn up it prevents its contents from spilling over the edge, a thing which might otherwise happen with a boat pitching in a heavy sea.

From the iron ring which supports the broader end of the cone depends the net proper (*nt*). The net is a cone with a slant height of about 100 cm. It consists of No. 20 silk bolting cloth, a very strong fabric, which contains many very small openings of uniform size. This cloth or gauze has the further advantage of not undergoing changes in water and of not yielding any lint to contaminate the plankton. The outside of the gauze net is protected by a twine net of inch mesh, which serves to take up the strain on the gauze net when it is being drawn through the water.

The lower end of the gauze net does not run to a point, but is truncated and attached to a flat metal ring. To this ring there is attached a bucket (*bk*), which is shown separated from the net in fig. 2, A. In order that the weight of the bucket may not be borne by the net, six stout cords (*crd*) run from the upper net ring to the lower net ring, and are made of such length that they support the weight of the bucket. The bucket is essentially a metal cylinder about 6 cm. in diameter inside and 6 cm. deep. It is supported on three legs. At the top it is arranged to be attached to the bottom ring of the net by means of three binding screws. The sides of the bucket are cut away as much as possible, so as to leave only six narrow strips of metal, and the windows thus formed are filled with gauze like that of the net. The bottom of the bucket is conical and has at its middle an outlet tube, closed by an accurately fitted plug, which may be removed from the inside. This plug is shown separately at fig. 2, B.

The whole net is suspended by means of three cords from a support consisting of three radiating arms. At the junction of the three arms is a strong iron ring, from which runs a rope, by means of which the net is drawn up. The rope is graduated in feet, or fractions of a meter, so that one may read off the depth to which the net descends. By holding in the hand the tri-radiate support from which the net hangs the latter may be kept from twisting on the supporting rope.

In working, a spar is lashed to the upper deck of the steamer, so that its end extends about 4 feet beyond the side of the vessel. To the end of the spar is lashed a pulley, through which the net rope runs. The net is then allowed to sink. In going down it takes in no water except that which is filtered through the gauze. It is sometimes let to the bottom and sometimes to a depth of only 2, 4, or 6 meters. It is then drawn up by hauling in the rope hand over hand. The net is always hauled up by the same person and note is made of the number of seconds between the time it leaves the bottom and the time the top of the canvas cone reaches the surface. From this time the velocity of the net is determined. The net is then drawn out of the water and allowed to hang at the end of the spar while the water drains out of it. At the same time a stream of water from a hose is turned upon the outside of the net. This water is filtered in passing through the net gauze to the inside, so that it does not add anything to the material captured in the net. The stream washes all the plankton into the bucket beneath.

After the water has partly drained out of the bucket, the binding screws are loosened and the bucket is removed and taken into the cabin. Here nearly all the water is allowed to drain out through the gauze sides of the bucket and the plankton adhering to the inside is washed down into the conical bottom by means of a stream of filtered water from a wash bottle. All the material taken in the net is thus collected into the conical bottom of the bucket. A small glass beaker is then placed beneath the tube in the bottom of the bucket, the plug is removed, and the plankton falls into the beaker. The inside of the bucket and the plug are then rinsed several times in filtered water and the rinsing water is added to the material in the beaker. The small quantities of material obtained necessitates great care in handling lest some of it be lost. The substitution of a plug in the bottom of the bucket for the stopcock used by Apstein is believed to be an advantage, in that it allows the inside of the tube to be rinsed with greater thoroughness.

The small quantity of material now in the beaker contains very minute forms. If this material be turned into a bottle of some fixing or killing fluid, and if this fluid be afterward poured off and alcohol substituted for it, some part of the material is sure to be poured off and lost. After much experimenting we finally hit upon the following device for preserving the material:

A short 6-dram homeopathic vial has its bottom removed and edges annealed. The bottom is then closed by tying over it with fine silk thread a piece of the No. 20 gauze, such as is used for the net. The contents of the beaker are poured into this tube, and by gentle tapping the water is made to filter very rapidly through the gauze bottom, leaving the plankton in the tube. Before all the water has filtered away a label is placed in the tube and the open end is closed by tying over it a piece of the gauze. The tube (see fig. 3) is then placed with other tubes in a large bottle of fixing fluid. (We used alternately Flemming's solution and Kleinenberg's picro-sulphuric acid.) The tube is then passed through successive grades of alcohol (preceded by water in the case of the use of Flemming's solution), and is finally preserved in 82 per cent alcohol. In passing the tube from one fluid to another it may be emptied of its fluid by forcing air into it by means of a pipette held against the gauze at either end. When the tube, emptied of its fluid, is placed in the next fluid it may be filled by immersing it in the fluid and removing with a pipette the air previously forced in. This method prevents the loss of plankton in the manipulation, and it also saves much time and enables one to pack many tubes of plankton in a single large vessel.

When the plankton has been preserved in the tubes they must be taken to the laboratory in order to carry out the rest of the work. Here the contents of each plankton tube are measured in the following manner: The gauze is removed from one end of a tube and carefully rinsed free from any adhering plankton. The alcohol used in rinsing is placed in a beaker and the contents of the tube poured into the beaker. The tube and the other gauze are thoroughly rinsed and the rinsings placed in the beaker. The contents of the beaker are now turned into a tube graduated to tenths of a cubic centimeter. This tube is allowed to stand twenty-four hours in order that the lighter constituents of the plankton may settle, and the volume is then read off and recorded.

The volume thus obtained is the volume of plankton taken by the net in drawing it vertically through, let us say, a distance of 200 cm. The area of the opening into the net is about 1,250 sq. cm. Hence the net might be thought to have filtered a volume of water equal to the area of its opening multiplied by the distance through which it is drawn. On this assumption the net would have filtered, in this case, 1,250 by 200, which is 250,000 c. c. of water, and the volume of plankton taken (perhaps 1·5 c. c.) would be the volume contained in 250,000 c. c. of water. Since the gauze net offers considerable resistance to the water it is not true that the net filters the whole of the column of water through which it is drawn; on the contrary, a part of this column is forced aside while another part passes through the net. The proportion of water which passes through the net depends upon the velocity of the net. Let us suppose that it is one-half of the whole column; then the 1·5 c. c. of plankton taken represents not the amount in 250,000 c. c. of water, but the amount in 125,000 c. c. of water. To get the volume of plankton in 250,000 c. c. of water, we must multiply the volume taken by 2. Similarly, under whatever circumstances the net is drawn, if we wish to know the amount of plankton contained in the column of water through which it is drawn we must multiply the volume of plankton taken by some number which represents the relation of the volume of water strained to the whole column of water through which the net is drawn. This number is called the coefficient of the net.

In the case of our net the volume taken when multiplied by the net coefficient gives the total volume of plankton under an area of 1,250 sq. cm. of the lake surface. In order to get the area under one square meter of lake surface this number is multiplied by 8 (1,250 c. c. is one-eighth of a square meter). The coefficient of the net used is now being investigated, but has not yet been accurately determined, so that the reduction of the volume taken to the actual volume and to the volume under a square meter of surface can not be attempted at this time.

The following table shows the results obtained by measurements of the volumes taken at five of the stations. The volumes taken at the other stations, with the necessary reductions and a fuller discussion of the results, will appear in the forthcoming bulletin of the Michigan Fish Commission:

Schedule of the hauls of the vertical net.

Date, 1893.			Number of haul.	Depth of water in meters.	Depth of haul in meters.	Temperature of water in degrees centigrade.		Temperature of air, in degrees centigrade.	Wind.	Sky.	Water.	Volume taken in cubic centimeters.
Month.	Day.	Hour.				Top.	Bottom.					
IX	8	11:10 a. m	III *q*	5·94	5·54	17.2	17.2	19.2	NE. 1	Cloudy	Slight waves	·90
		11:30 a. m	III	5·94	5·54	"	"	"	NE. 1	do	do	1·27
		11:45 a. m	III^2	5·94	4·50	"	"	"	NE. 1	do	do	·80
		1:15 p. m	III^3	5·94	3·00	"	"	19.8	NE. 2	Cloudy and sunny	do	·98
		1:30 p. m	III^4	5·94	1·50	"	"	"	NE. 1	do	do	·87
	9	10:40 a. m	V *q*	5·66	5·26	18.2	17.9	19.8	SE. 1	do	Moderate swell	·90
		11:00 a. m	V	5·66	5·26	"	"	"	SE. 1	do	do	1·19
		11:15 a. m	V^2	5·64	4·50	"	"	"	SE. 1	do	Swell and waves.	·83
		11:30 a. m	V^3	5·64	3·00	"	"	"	SE. 1	do	do	·63
		11:45 a. m	V^4	5·64	1·50	"	"	"	SE. 1	do	Not so rough as V^3.	·54
	10	1:45 p. m	IX *q*	4·69	4·28	18.4	18.1	25.	N. 1	do	Slight waves	·66
		2:00 p. m	IX	4·69	4·28		"	"	N. 1	do	do	·62
		2:10 p. m	IX^2	4·69	3·00	"	"	22.8	N. 1	do	Moderate waves.	·68
		2:30 p. m	IX^3	4·69	1·50	"	"	"	N. 1	do	Slight waves	·42
	17	10:30 a. m	XIX *q*	4·78	4·37	18.1	18.1	......	NW. 3	Clear	Rough	2·43
		10:45 a. m	XIX	4·78	4·37	"	"	......	NW. 3	do	do	4·50
		11:00 a. m	XIX^2	4·78	3·00	"	"	......	NW. 3	do	do	3·29
		11:45 a. m	XIX^3	4·78	1·50	"	"	......	NW. 3	do	do	2·66
		3:15 p. m	XX	8·84	8·43	18.9	18.6	17.7	N. 1	Hazy	Smooth	2·47
		3:30 p. m	XX *q*	8·84	8·43	"	"	"	N. 1	do	do	2·50
		4:00 p. m	XX^2	8·84	6·00	"	"	"	N. 1	do	do	1·75
		4:15 p. m	XX^3	8·84	3·00	"	"	"	None	do	do	1·97
		4:30 p. m	XX^4	8·84	1·50	"	"	"	None	Foggy	do	1·43

The fourth column contains the arbitrary number given to each haul of the net. The Roman numerals indicate the number of the station. Two hauls were always made from the bottom; one of these, distinguished by the letter *q*, is intended to be used for qualitative work, the other is indicated by the station number only. The small Arabic numerals affixed to the remaining station numbers serve to indicate the different hauls which do not reach the bottom, the number 2 indicating the haul made from the greatest depth. The fifth column gives the depth of water and the sixth the depth from which the net was hauled. When the net is hauled from the bottom the depth from which it is hauled is reckoned from the top of the canvas cone. It equals the depth of water minus the height of this cone. The remaining columns give the temperature of air and water in degrees centigrade, the direction and strength of the wind, and condition of the sky and water. The last column gives the volume taken.

The same net was used for all the hauls, and if we assume that it was drawn in each case with the same velocity, then the volumes taken in the different hauls may be directly compared with one another without applying the correction. It is not possible to compare the measurements shown in this schedule with those given by Apstein for European lakes, until the measurements here given have been reduced to show the volume under a square meter.

Stations III, V, and IX are in Lake St. Clair, while stations XIX and XX were in Lake Erie near the Put in Bay Islands. The following facts are evident from an inspection of the schedule:

1. There is about three times as much plankton at stations XIX and XX in Lake Erie in the month of September as at any of the stations in Lake St. Clair.

2. The hauls made by letting the net down but a little way from the surface contain nearly as much plankton as those made from the bottom at the same stations. Thus at station III the two hauls from the bottom yield an average of 1·09 c. c., while a haul (III, 4) made from a depth of but 1·5 meters contains 0·87 c. c. In the case of station V the amount falls from an average of 1·05 for the bottom haul to ·54 for the 1·5 meter haul. In the case of station IX the numbers are 0·64 c. c. and 0·42 c. c., respectively. It thus appears that one-half or more than one-half of all the plankton occurring in water 5 meters deep is in the upper 1½ meters of the water. A similar result was reached by Apstein. Whether the plankton maintains the same relation to the surface at night or at other seasons of the year requires further investigation.

After having determined the volume of plankton in any locality it is possible to count the number of animals and plants of each species occurring in the volume of plankton taken. The method of accomplishing this has been worked out by Hensen, and is essentially as follows: Let us suppose that 1 cubic centimeter of plankton has been taken. One-tenth or one-hundredth of this is spread on a glass plate upon which parallel lines have been ruled with a diamond. Hensen has devised means by which the one-tenth or one-hundredth part may be accurately measured. The glass plate is then placed upon the stage of a specially constructed microscope. This stage is provided with a suitable carriage actuated by micrometer screws, and upon this carriage the glass plate may be moved about, so that it is possible to examine all parts of it. The number of each species of animal and plant upon the plate is then counted, the lines serving to separate the forms counted from those still to be counted. By thus counting the forms contained in a tenth part or a hundredth part of the plankton taken the number contained in the whole plankton taken may be calculated. It is then possible to calculate the number of animals of any one species occurring under a square meter of surface. It is possible also to calculate the numbers of any species at any depth. Thus we may find that in a haul made from a depth of 3 meters there are 2,000 cyclops, and in a haul made at the same time and place, but from a depth of 1½ meters, there are but 500 cyclops. We have, then, the number of cyclops contained in the whole column of water (3 meters long) and the number contained in the upper half of this column (1.5 meters long). The difference between these two numbers must be the number of cyclops contained in the lower half of the column of water. In other words, then, 1,500 cyclops are living in a known volume of water, let us say 1 cubic meter, at a depth of from 1½ to 3 meters. By this method of counting the number of forms in each column of water and by subtracting the contents of one column from the contents of another we may know at what depth each form lives and in what numbers. We may also know what its migrations are at different hours of the day and at different seasons of the year.

The plankton taken in Lake St. Clair has not yet been counted, owing to delay in procuring apparatus, but it is hoped this will be accomplished during the year.

The fish-culturist and the fisherman will now wish to know what practical results have come from our work. The work was undertaken as a scientific problem, the determination of the biological conditions existing in the lake. This problem is very large and will necessarily, more especially if extended to the whole chain of lakes, involve the work of many investigators for many years. It is believed that the past summer's work is a step toward its solution. Any operation of practical fish-culture which involves Lake St. Clair is likely to be guided to some extent at least by the data which we have collected.

It must deal with a shallow, roily lake, poor in plankton and in littoral forms, but rich in bottom fauna and flora. Bottom-feeding fish which are adapted to roily water of this temperature will find here a rich pasturage. This is illustrated in the case of the carp, which seems to have made its way into the lake through the small tributary streams. This fish is multiplying rapidly and is of excellent quality.

It was hoped that we should find in the lake the young whitefish and that we might be able to determine the conditions under which this fish lives. In this we were disappointed. It is possible that a search begun earlier in the season and with more elaborate apparatus would succeed. It is manifestly not possible to say whether or not the lake is a suitable one in which to plant whitefish, until we know the habits of the fry. If the fry feed only upon the minute crustacea of the surface plankton, as Forbes found them to do in confinement, then they would find food much more abundant in the region of the Put in Bay Islands in Lake Erie than in Lake St. Clair. If they feed upon the many small animals which inhabit the bottom vegetation (this is the habit of the adult whitefish) then it would be hard to find a better place than Lake St. Clair.

The Michigan Fish Commission has made a beginning in the investigation of the biology of the Great Lakes. It has shown great foresight in instituting the work, has provided liberally for it, and has not hampered it by unwise restrictions. Such an investigation, carried out as a scientific enterprise, without restriction, is sure to yield results of the utmost value to the fisheries. This statement needs no other justification than is contained in the facts alluded to at the beginning of this paper, the fact that both the fish-culturist and the fisherman are dealing with a problem with but little knowledge of the nature of the materials involved. Let them study to understand the nature of these materials. Let us have a biology of the Great Lakes and we shall have both fish-culture and fishing on a surer basis.

To build up a knowledge of the biology of the Great Lakes must take the time of many men for many years, and must require the expenditure of large sums of money. It is an enterprise that should commend itself to every State which has an interest in fish-culture in the lakes. Especially should such an enterprise commend itself to the commercial fisherman, as he has much to gain by it.

18.—THE AQUARIUM OF THE UNITED STATES FISH COMMISSION AT THE WORLD'S COLUMBIAN EXPOSITION.

REPORT OF THE DIRECTOR.

BY S. A. FORBES,

Professor of Zoölogy, University of Illinois.

The aquarium of the United States Fish Commission was universally regarded as one of the most attractive features of the World's Columbian Exposition, having been a source of wonder and delight for months to several millions of people.* Its early readiness for the visitors, at a time when most of the exhibition areas were cheerless wastes of seemingly hopeless disorder, gave it a prompt popularity, which neither the inspirations of the Art Gallery, the diversions of the Plaisance, nor the glories of the Court of Honor served at any time materially to lessen. It was a place of marvels for the populace, and especially for the native of the Mississippi Valley, who, although an industrious fisherman, may rarely have seen a fish distinctly in the muddy waters of his streams and lakes, and to whom the forms and actions of many of the most abundant animals of the sea were as novel as if the contents of our tanks had been made to order for our special use.

A brief account of the means and methods by which these results were reached in the space of a few months; of the difficulties inherent in the plan and in the situation; of the failures and successes of the enterprise—both sufficiently numerous to make the administration of it a decidedly interesting task; and especially of the new facts and experiences resulting, may perhaps be profitable to others in kindred fields, and even deserving of some attention from a larger public.

An aquarium is intended to be a bit of aquatic nature brought within the easy reach of man, with as little disturbance of natural conditions and relations as the circumstances will permit, and with the most faithful representation possible of such conditions and circumstances as it is nevertheless necessary to disturb or destroy. Its only worthy dependence for sources of interest is on that love of nature, and especially of living nature, common among unspoiled men, and often the redeeming trait of those otherwise quite sophisticated. To present and represent living nature faithfully, without unworthy tricks to catch attention, and especially without falsehood or any other kind of deception, but still to do this by means and in a way which will justify

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NOTE.—This article, intended originally for the Fisheries Congress held in October, 1893, has been revised in part, to include results reached during the closing days of the exposition season.

* For some hours each day, during a large part of the season, entrances to the aquarium averaged from 100 to 150 per minute, packing the corridors to the limit of their capacity. Many thousands daily were turned back at the doors by the overcrowded condition of the building, or forced to content themselves with a hurried and distant glance at the exhibit.

and heighten one's delight in the natural world by recalling pleasing experiences, by introducing novel objects, and by conveying agreeable or important information, is the task of the aquarium manager, as it is that of the director of the zoological garden and that of the curator of the natural-history museum. To use aquarium material merely for display and not mainly for instruction is as silly as to attempt to make butterflies more beautiful by arranging them in the form of a star; and to put into the water with an imprisoned living animal anything which misrepresents it to an ordinary observer is not only mischievous, but base.

These are high principles, and in an exposition aquarium as large as ours, repaired, finished, furnished, and stocked in three months of almost unexampled winter and one of stormy spring, it was not, of course, always as easy to live up to them as if one could have had the advantage of some years of leisurely preparation. But we did as well as we could, more conscious than anyone else could be of the distance between ideal and realization, and glad all along that we had so much for our visitors to look at that they rarely thought of the things which we could not get.

January 1, 1893, the Aquarium annex of the Fisheries Building was as cold as an ice-house, its tanks all unfinished, black caverns of asphalt dimly seen through dirty glass, most of them leaky (as we found when it became warm enough to permit us to let water into them) and the water-pipes burst by freezing all over the building—a discouraging wreck, much of which had finally to be taken down and replaced.

The principal things to be done with the least possible delay were to test the sufficiency of the aquarium tanks and to make such changes and repairs as this test should show the need of; to finish suitably the interior of these tanks with such naturalistic and decorative work as would make them a fit home for the various aquatic forms they were to contain; to get the earliest possible start of aquatic vegetation as a further naturalistic decoration; to repair the burst and broken water-pipes for the conveyance of water, salt and fresh, to the tanks and away again; to get the heating plant enlarged so that water might be admitted to the building without danger of freezing;* to provide a pool or inclosure for the reception of fishes as brought in, that suitable selection might be made of uninjured and vigorous specimens for the aquarium, and that a good stock might be kept in hand from which the aquarium tanks could be replenished as disease or accident should make this needful; to introduce filters for the salt and fresh water, neither of which had as yet been provided; to plan and manufacture apparatus for the warming of the water in spring and fall and for its cooling in midsummer; to complete and test the electric pumping outfit for the circulation of the salt water; to bring, nearly a thousand miles from the sea, a supply of salt water sufficient to fill aquaria of a capacity of 40,000 gallons, together with a pumping supply in the huge cisterns of the sea-water system; and, most difficult and responsible task of all, to accomplish the object for which all the rest was planned, namely, to assemble collections in extraordinary number and in the largest possible variety from the Great Lakes, from the rivers and smaller streams of the interior, from both oceans, and from the Gulf, such as should illustrate the aquatic fauna of the country properly and in a way to justify the large expenditures already made and and those still needed for the completion of the exhibit.

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* The temperature in the aquarium annex fell at one time to 11° F. while the heaters were carrying all the steam allowed.

The weather of the winter and spring was an almost uninterrupted succession of storms, which embarrassed and delayed preparations in Chicago and practically broke up again and again our field operations on the Great Lakes and on the Illinois and Mississippi rivers; nevertheless, May 1, "opening day," the aquarium was in good working order throughout, with the interior decoration of the tanks completed; nearly all were stocked fairly well—some profusely—with a good variety of marine animals and fresh-water fishes; and the machinery of maintenance and further supply was thoroughly organized and at work on a scale to insure an abundance of material throughout the season. By June 1 we had probably the largest collection of fresh-water fishes in number and variety ever brought together in the world, and a marine exhibit which, considering the great distance from the sea, reflected the highest credit on the officers and men of the Commission whose energy and resources had brought it together.

Without entering into unprofitable detail of our experience, I have thought it desirable to give here such a description of our plant and equipment and of certain special features of our work as may be supposed to have a value for the guidance of others similarly engaged, together with such contributions to biological knowledge as we were able to make under the peculiarly disadvantageous circumstances surrounding us in the midst of the rush and turmoil of a great exposition season.

The Fisheries Building was erected and equipped by the Exposition Company substantially according to plans made by the architect, Henry Ives Cobb, the aquarian management having had nothing to do with plans or construction previous to January 1, 1893, at which date the aquarium annex was transferred to the control of the U. S. Commissioner of Fisheries, and by him placed in charge of the writer. This annex or wing, connected with the main building by an open corridor, had the form of a circle 131 feet inside diameter. The outer walls were comparatively low and the roof conical, the interior part of the cone being elevated above the outer part upon a low wall with many windows. The aquarium tanks were arranged in two concentric circles: an outer circle of smaller tanks with glass fronts within lighted by windows in the outer wall of the building and by heavy glass in the roof above; and an inner circle with both outer and inner faces glass and lighted only from the roof, the two being separated by a passageway 15 feet wide. This aisle was so shut in above by a vaulted ceiling that the only light admitted to it, except that from the general entrances to the building, reached the spectator through the glass fronts of the aquaria.

Between the outer circle of aquarium tanks and the wall of the annex was a narrow passage for the attendants, who were of course thus behind the scenes when at work. The inner tanks were reached by ladders going from this passage over the vaulted ceiling of the aisle above mentioned and thus also concealed from view. Above both sets of aquaria were panels of darkened glass (covered by us with heavy felt), some of which were hinged to permit the introduction of specimens to the tanks. The central portion of the room was occupied by a circular pool 26 feet across, separated from the inner circle of tanks by a corridor or aisle about 15 feet wide and lighted by windows in the vertical part of the roof.

The entire glass frontage of the aquaria amounted to 665 linear feet, approximately 3,000 square feet in all, the total capacity of the 50 tanks being 140,000 gallons, of which about 40,000, in 15 tanks, were devoted to the marine exhibit. The central pool contained about 6,000 gallons of fresh water additional. The tanks of the outer series were in two sizes, all rectangular in shape, the smaller (24 in number) with a frontage of 5½ feet and a width from before backwards of 3¾ feet at bottom and 5½ feet at top; the larger size (16 in number) of twice the above length, but of the same dimensions otherwise. The inner tanks were in three sizes, the 8 smallest with a frontage of 15 feet outside and 11½ inside, the next (a single tank) of double these dimensions, and the third (likewise a single tank) 56 feet long on the middle line, with glass frontage of 60 feet and 46 feet linear, on the outer and inner faces respectively. All the tanks of the inner circle were 8¾ feet from front to back.

The fresh water was derived from Lake Michigan through the general water supply of the park and passed through pressure filters* of a nominal capacity of about 10,000 gallons an hour, but sometimes worked by us at three times this rate. In order to secure the perfect clearness of water indispensable to a proper display of our material it was found necessary to introduce an alum tank into the circulation, provided with an automatic regulator by which a fixed proportion of alum in solution was mingled with the water before it passed through the filters. The flocculent precipitate thus formed by the union of the alum with the mineral matters of the lake water so entangled all minute suspended particles that they were taken out by the fine quartz sand of the filters, leaving the water beautifully clear and also chemically free from any surplus of alum. Provisions were likewise made for warming this water, when necessary, after it emerged from the filters, by passing it through a coil of brass tubing encased in a large piece of heavy iron pipe filled with steam from the boiler used in heating the building.

A receiving pool, in three divisions, was made in the lagoon by inclosing and subdividing an area along shore, adjacent to the aquarium, with a fence of wire netting fastened to heavy wooden posts. As the water level varied greatly with the direction of the wind, a seine with numerous floats was attached to the upper border of this fence. The extremely unfavorable character of the weather early in the season prevented the rapid accumulation of large quantities of specimens for which we had planned and prepared, and this pool was consequently but little used. But for this unforeseen and unavoidable delay we should have escaped many of the subsequent difficulties of aquarium maintenance. It was a part of our original plan to store our field fresh-water collections—especially those brought from considerable distances—in this pool, leaving them there until those injured in transit or diseased had either died or recovered, selecting then from the remainder, from time to time, what were needed for the aquaria. Pressure of time and a determination to be "ready May 1" usually compelled us to add the fresh material to the exhibit as fast as it came in.

The first installment of salt water—to the amount of 42,000 gallons—was transported from the sea at Beaufort, N. C., in seven tank cars loaned to the Commission by the Standard Oil Company, and hauled by the Chesapeake and Ohio Railroad free of charge. The salt water circulating system† consisted of an underground cistern 46¾ feet long, 18⅔ feet wide, and 8½ feet deep, a pressure tank in the roof of the main Fisheries Building 30¼ feet in circumference and 5 feet deep, supply pipes of hard rubber leading from the latter tank to the aquaria, return pipes of the same material conveying the water from the aquaria to the underground cistern, and hard-rubber electric pumps of a capacity of 3,000 gallons per hour, by which the water was lifted from the underground cistern to the tank in the roof. Between the aquaria and the cistern was inserted a sand and gravel filter, and between the roof tank and the aquaria a heating apparatus like that provided for the fresh water. This heater was used, however, chiefly as a cooler by passing a current of lake water through the inner coil. The pumps were in duplicate, only one being in service at a time. These and the rubber tubing connected with them were made to order by the Rubber Comb Company of Rochester, N. Y.

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* Furnished, put in place, and maintained gratuitously by the O. H. Jewell Filter Company, of Chicago.

† A technical description of the circulating plant of the aquarium, prepared by Passed Assistant Engineer I. S. K. Reeves, chief engineer of the Commission, is appended to this article.

The fresh water entered the tanks by means of numerous jets, from which it escaped with sufficient force to carry the air well towards the bottom. We found it desirable, however, to maintain a more efficient bottom circulation by attaching rubber tubes to some of these jets. In the marine aquaria the salt water was similarly introduced to the tanks, but an additional aërating apparatus was provided in the form of an automatic air-pump working by water pressure obtained from one of the fresh-water supply pipes. From this pump air was distributed to all the salt-water tanks, at the bottom of which it escaped in the form of clouds of minute bubbles forced through plugs of basswood inserted in the sides of rubber tubes. This highly successful device for the subdivision of the air is the result of a series of experiments made by Mr. Harron, of the U. S. Fish Commission, under the instruction of the Commissioner.

The tanks were decorated internally with great skill and ingenuity by Mr. J. B. Mora, of Chicago. For the salt-water aquaria a calcareous tufa had been obtained, at a cost of about $30 a carload, at Toledo, Ohio, where large deposits of it are quarried for use in the manufacture of paper. It came in selected shapes admirably adapted to decorative work. As we could not foresee the kinds of marine animals which it would be possible to secure, no especial naturalistic effects were attempted in the decoration of the marine aquaria, but generalized grotto-like and other ornamental designs were worked out with charming result. This same material was used for a massive central rockwork in the pool, from the summit of which the water fell in cascades and trickling streams.

The interior finish of the fresh-water tanks was carefully planned in advance with reference to the favorite haunts and native surroundings of the principal classes of fishes which we might expect to obtain. Muddy river banks, bluffs, and islets of stratified rock, ponds with sunken logs, pebbly lake shores, margins of pools, submerged trees and stumps, the water-logged rubbish of an old boat landing, fallen brushwood and the like, and rocky beds of streams with mossy incrustations were all admirably reproduced, in the only manner practicable with the time at our disposal, in cement, sand, and gravel. For the purely ornamental fish, like golden ides, goldfish, and the more brilliant minnows, aquaria were decorated in a purely fantastic manner, with a view simply to heightening the artistic attractiveness of the collections.

Most of our internal decorations were originally designed in expectation of adding to them effects to be derived from aquatic vegetation appropriate to the habits and environment of the various kinds of fish. For the purpose of getting an earlier start of aquatic plants than could be had from the vicinity, collections were made throughout January and February at Eustis, Fla., and shipped to the aquarium early in March. This part of our preparations failed, however, in part because of the unseasonable weather which froze or severely chilled the plants in transit, and partly because of the long delay in the manufacture of the heating apparatus for the fresh-water circulation, which was, in fact, not ready for use until all need of it had long passed by. As the water of the lake was but a few degrees above freezing when our southern collections arrived, they could not be made to grow in place, and presently perished. Experiments were made by the gardener, engaged for this purpose, at starting these plants in water warmed by the direct introduction of steam, and also in the conservatories of the city parks, but all practically failed, and it is evident that the shock of the transfer and change of condition was too great. After the season opened at the North a new embarrassment arose, due to repeated attacks of fungous fish disease, with the germs of which we found the Lake Michigan water supply to be continuously loaded. As the only practical method of combating this disease required the frequent use of salt in the aquarium tanks our water plants perished almost as fast as they were introduced, and we were finally obliged to give up all attempt at plant decoration.

Our organization for fieldwork was completed by the assignment of cars and men for collections at Quincy on the Mississippi and at Meredosia on the Illinois; at Put-in Bay on Lake Erie; at Beaufort, N. C.; and, later, at Woods Holl, at Tampa Bay, Fla., and at Monterey, San Francisco, and Puget Sound on the Pacific coast. The Fish Commission stations at Leadville, Colo.; Neosho, Mo.; Northville, Mich.; Green Lake, Me., and the Central station at Washington, were also repeatedly laid under contribution during the season. A lot of magnificent specimens of bred trout was sent us from the New York Fish Commission station at Caledonia, N. Y., and large and valuable contributions of superb aquarium material were accumulated for us from time to time at Spirit Lake, Iowa, by Mr. T. J. Griggs, fish commissioner of Iowa. The three regular cars of the U.S. Commission were placed under the orders of Dr. S. P. Bartlett, at Quincy, and of Mr. J. J. Stranahan, at Put-in Bay, and a new car, intended for transporting marine material, was bought by the Commissioner and equipped with large tanks and an aërating apparatus.

Our special purpose in making our marine collections was somewhat different from that governing our fresh-water work. For the former we sought objects of popular interest; examples of well-known food-fishes (as the salmon, red snapper, sheepshead, and pompano); animals especially attractive because of their size, their extraordinary forms and actions, their beauty, or their peculiar habits and modes of life (sharks, sea-anemones, starfishes, hermit crabs, and remoras, for example); finally, the oddities and monsters (skates, flounders, toadfishes, burrfishes, sea-robins, and the like). We wanted, in short, the food-fishes, the beauties, and the wonders of the sea.

The fresh-water collections, on the other hand, were planned primarily to give to the uninstructed visitor a fair general idea of the fish fauna of our interior waters, not preferring any class or kind over another, but reproducing, as nearly as practicable under our conditions, a symmetrical picture of the fish life of the lakes, rivers, and smaller streams of the interior United States. A few specially brilliant exotic species were introduced to relieve the otherwise too somber effect of the fresh-water exhibit; and as an accessory object we undertook also to illustrate, to some extent, the results of scientific fish-culture, as carried on at the stations of the U. S. Fish Commission.

In the assignment of tanks the smaller ones were used as a rule to display species and varieties so grouped and labeled that the observer could distinguish kinds and learn their names; the larger ones to exhibit groups, either natural families or mere assemblages living together in the same waters. The 60-foot tank, for example, showed the fishes of the Mississippi River and its larger tributaries; the sunfish family were displayed in another 13 feet long; numerous examples of the minnow family and other smaller species were thrown together in still another aquarium of intermediate size.

The central pool was used for a time as a receiving tank in which cars of live fish were unloaded as they came, kept until adjusted to their new conditions, and then transferred to their proper aquaria. It usually contained, consequently, a miscellaneous assemblage of material from all sources, and was made the permanent home of several of our largest fresh-water specimens.

The pioneer inmates of the new aquarium, a lot of 6,000 young lake trout, yearlings and two-years old, came from the Northville station March 21, and remained for many weeks a principal ornament of our exhibit. Next followed a large load from Washington, mostly carp and ornamental fish. Then, April 10, another car came in, the first from the field, containing a thousand specimens, representing 26 river species.

Storms blew from every quarter, driving our crews out of the lake again and again, and floods arose until rivers were miles wide on our principal collecting-grounds. But what we could not do in one way and place we usually managed to do in some other, and by May 1, 11 carloads had arrived, large and small, 5 of them fresh-water collections, 4 of bred fish from the stations of the Commission, and 2 from the Atlantic on the Carolina coast. Thus, on "opening day," we had in our tanks numerous representatives of 60 species from rivers and lakes, and of 42 from the sea.

Field collections were continued throughout the summer, as required to maintain and improve the exhibit, and especially to make good our heavy losses from disease. Not less than 50 carloads of specimens were received from all sources between March 21 and October 9. Of these, 7 came from the Great Lakes; 5 from smaller lakes, mostly from Spirit Lake, Iowa; 15 from the Mississippi and Illinois Rivers, and 4 from smaller rivers and streams, including the grayling streams of northern Michigan—31 in all from fresh-water situations. To this number may be added 6 carloads of fresh-water species from the stations of the U. S. Fish Commission, and 1 from the New York Fish Commission station at Caledonia in that State. Twelve carloads came in from the sea, 5 of them from Woods Holl, 4 from the North Carolina coast, 2 from the Pacific (California and Washington), and 1 from the Gulf at Tampa Bay, Fla. The total number of species and well-known varieties represented in the aquarium during the season by living specimens was 208; 93 of these were marine and 115 were fresh-water forms; 102 of the latter and 54 of the former were fishes; the remaining 39 of the marine species were miscellaneous invertebrates.

The force in charge consisted of a director, whose duties were mainly administrative; two superintendents, one for the fresh-water aquaria and one for the marine; two attendants for the latter, both engaged the greater part of the time in policing the tanks, feeding, and otherwise caring for the fish, and, at intervals of a day, in emptying, washing, and repacking the sand and gravel filter. On the fresh-water side five attendants were required, their time being so divided that three were usually present at once. The care of the aquarium at night required the attendance always of one and sometimes of two of the above force. In the pump-room were three engineers, and the services of a fireman were needed when heat was wanted in the building. One additional employé collected minnows as food for species which could not be fed otherwise, attended to the reception and transfer of fresh collections, and made himself generally serviceable within and without the aquarium.

I have neither time nor inclination to enter into a systematic history of our operations during the season, but will only select from the items of our experience some of those which seem to me the most interesting or the most profitable for future guidance.

First, with reference to the planning and arrangement of the aquaria. Impressive and pleasing as is the general effect of the circular disposition of our tanks, I would not now plan a circular building like ours for an aquarium in which great crowds of visitors were to be received. Something is lost in the fact that few of the aquaria can be seen at once, but the lack of sufficient provision for a free movement of the air through the corridors is a much greater defect. The two double-doored entrances were distant from each other only a little over a fourth of the circumference of the building, and the radiating passages leading inward from them cut the circular corridors between the rows of tanks into two very unequal segments, one approximately 75 feet long and the other 190 feet. In this longer passageway the air was practically stagnant much of the time, and often so offensive with the emanations of the crowd that sensitive persons could not stay in it. A rectangular building with opposite entrances at ends and sides would have permitted a much freer movement of both air and people. Still better, perhaps, would have been a structure in the form of a Greek cross, with a low central dome and entrances at the ends of the arms.

My summer's experience fully convinces me that in the large fresh-water aquarium the deep glass-fronted tank should be in great measure replaced by shallow basins or pools or basin-like tanks borne on raised foundations, or with sunken walks between, and left freely open above to both air and light. These basins should not be set so low as to give a distorted view of the fish when looked down upon from above, nor so high that a person of average height might not readily see to the bottom while standing a little distance away. If the bottom were saucer-shaped, with shallow water at the edges, minnows and larger fish might well be kept together with charming effect, and suitable plant decorations could be introduced without obscuring unduly the view of the interior. Among my reasons for a preference of the open pool is the advantage thus gained in the inevitable struggle with parasitic fungi infesting fresh-water fish. As the salt-water species are free from this difficulty, there is no objection, so far as they are concerned, to the closed tank now in general use. It is clearly a great error, however, to plan any large aquarium without provision for small open tanks in which the smaller animal forms may be shown to good advantage, and especially those which may best be seen from above. This is as true of fresh-water animals as of ocean forms. Many of the oddest and most interesting aquatic creatures are too small to be commonly noticed, even if extremely abundant; but are large enough, nevertheless, to arouse great interest and repay careful observation if put in small, readily accessible tanks.

The comparative advantages of the open-pool system were continuously illustrated throughout the season by the history of our collections in the large central pool. In this basin, 2½ feet deep, with a surface area of 530 square feet and a bottom of white sand, trouble with fungous disease was at all times practically insignificant; while in the deep, narrow tanks adjacent constant and often unmanageable difficulty was experienced. This contrast is the more remarkable if we consider that the central pool was used as a receiving tank, and consequently often contained many specimens injured in transit. The shallow basin was also much more easily kept clean.

These conclusions are still further reinforced by the experience of the Illinois commissioners in a live-fish exhibit maintained in the Illinois State Building. Here still shallower pools with white enameled bottoms were used, supplied, as in our own central basin, by a dripping, splashing inflow of water falling from a considerable height. The miscellaneous collections in these pools were almost free from parasitic fungus attacks throughout the entire season.

The interior decoration of tanks of all descriptions with rock work and other naturalistic material is a matter of especial practical importance. These decorative materials should cover the interior surfaces, especially the backs and ends, but should not be so constructed as to occupy the interior of the tanks and thus obstruct a view of the contents. Especial care should be taken that no holes or crevices are left in which dead fish or other noxious objects may remain concealed. The best materials for naturalistic decoration are native rock, clean sand and gravel, and Portland cement. With proper cleaning down, repeated soaking, and thorough washing out, no contamination of the water need be feared, even with a closed circulation. Mud and clay, water-soaked wood, and the like, are of course inadmissible, and cement must be used for the imitation of these materials.

I need hardly add that in any well-constructed aquarium suitable storage and work rooms and offices of administration will be provided. It would, of course, be a great error in a permanent establisment to omit ample provision of laboratory rooms and appliances for systematic scientific study and experiment. These could be furnished at a slight addition to the first cost and could be maintained at a comparatively trifling expense. They would greatly increase the usefulness of any aquarium by making its resources available for the advancement of knowledge, thus enlisting the sympathy, aid, and support of scientific men and of the educated classes generally.

Our circulating apparatus for the salt water was, when supplemented and completed according to the plans of Engineer Reeves and the Commissioner, in every way satisfactory for summer maintenance, with the single exception of a lack of sufficient means for temperature control—a difficulty due to the character of the building and not to the circulating plant.[*] It is possible that a better plan of securing pressure might be devised than that of the use of the elevated tank. A closed underground cistern of air-tight construction, into which the water should be forced by the pump, depending upon air pressure within the cistern to send the water up to the aquarium tanks, has many features to recommend it for practical use. Steam, instead of electric pumps, would also have this especial advantage, that the power would be under the immediate control of the aquarium management, and not liable to possibly fatal interruptions through failure of connections, especially at night—an accident which we barely escaped several times.

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[*] The temperature of the salt water, beginning May 1 at 50°, reached 70° F.—regarded by us as the danger point for susceptible marine species—on June 19, but the second day afterwards fell off a degree. The 7th of July it came up to that point again, and remained between 70° and 74°, with only an occasional drop to 69½°, until August 12; 70° and 70½° were again repeatedly reached during the latter half of August, but the month closed with a temperature record of 67°. In September, 71½° was reached at the middle of the month, but the record fell to 61° and 62° for September 30. During October the thermometer readings varied from 67° on October 12 to 57° on the last day of the month, when the exposition closed. The highest temperature noted (74°) was reached July 25, with an average air temperature in the aquarium for the day (6 a. m. to 6 p. m.) of only 83°. These temperatures were reached notwithstanding the constant use of the cooler, the shading of the windows in the wall by cheese-cloth curtains, and the covering of the roof lights with an outside canvass screen.

The fresh-water record runs from May 1 to September 30, three daily observations being taken for the air and water. May 1 the lake water, as received in the aquarium tanks, stood without variation at 42° F., the air averaging 46°. The rise in temperature for May was gradual and steady, reaching 46° May 15, 50° on the 21st, and 55° on the 30th. It remained practically at this point until June 13, when it began to rise again, going somewhat irregularly to 65° on June 30. This rise continued to 70°, first reached July 11, and to our maximum record of 74°, made July 24, 31, and August 1. The fall from this highest point was gradual and very slow, the last observation (September 30) being 59

The fresh-water system, it will be remembered, was constructed for a continuous inflow of lake water, which ran away again after passing through the tanks. By this system an enormous quantity of water was required, amounting in our aquarium, during the warmest weather, to no less than 40,000 gallons an hour. Even at this rate it took nearly three hours to renew the water in the tanks, and a much greater supply would have saved us some heavy losses consequent upon trouble with a protozoan parasite presently to be described. In a permanent aquarium the cost of so large a quantity of water and the expense of filtration would be an important item in the maintenance.

By this method, also, everything depends upon the continuous integrity of the filter. We found the lake water to be heavily infected all the seasons through with the germs of fungous fish-disease. These fungous spores were largely removed by our alum filter, even when worked at two or three times its normal capacity; but, on the other hand, even a few hours disability of the filter not only resulted in an offensive clouding of the water, but was invariably followed by an outbreak of fungous disease all along the line of our tanks. It has consequently seemed to me possible that a closed circulation like that on the salt-water side might have given us a more perfect command of the aquarium and its contents, and possibly at even less expense than was involved in the system we used. If it had proven possible, under our conditions, to establish water plants generally in our tanks, this would, of course, have assisted in aëration, and a much smaller flow of water would have sufficed. It would have been necessary, however, even with "balanced" aquaria, to keep up a considerable movement of water through tanks carrying as heavy loads as ours, especially at night, when oxygen comes off slowly or scarcely at all from water plants, and fishes are consequently more liable to death from suffocation. For the *Salmonidæ*, especially in summer, a rapid and abundant flow is necessary; and for fish affected with the trout parasite, presently to be described, the water should run through the tanks in torrents day and night.

The great success of the aquarium season was the transportation and maintenance of our excellent collection of marine animals in their normal state of health and comfort. Ocean forms were never before carried alive over distances approaching those from Chicago to Florida and the Pacific coast, and, although many specimens fell by the way, the ratio of the lost to those delivered in good condition rapidly diminished with the experience of the car captains and their crews. The most successful trip of the summer, in fact, was that made by Capt. Lamson with a small load from Puget Sound.

The original supply of sea water was gradually increased by additional amounts brought in by the cars as they came with their loads, and by pouring into the filter from time to time a few hundred gallons of a simple solution of Turk's Island salt. The fixed density maintained was 24° by scale.*

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* The total amount of salt water received from the sea was approximately 50,000 gallons. To this 8,820 gallons of salt solution were added from May 3 to September 21, the largest amount at any one time being 1,080 gallons. Five hundred gallons of fresh water were used from October 1 to 9 to make good losses by evaporation and to maintain the proper density.

Fed with chopped clams and minced liver and beef, most of our specimens ate freely, became hearty and fat, healed their bruises and grew new tails when injured, and several species laid their eggs or reared their young as if still in their native haunts.[*] The smaller Atlantic sea-anemones only (*Metridium marginatum*) slowly dwindled with the advance of the season, not dying, but diminishing in size to a third or a fourth their original proportions. In the large, deep tank, which was the only one available for them, they could only be fed by mixing minced meat with the water, and this could not be supplied them in sufficient quantity without fouling the water to an injurious extent.

It was a great surprise to all concerned to find that a collection of marine animals in large variety and of the most interesting character could be maintained on the shore of Lake Michigan nearly a thousand miles from the seas, as easily and almost as cheaply as at Woods Holl, on the Atlantic coast—far more easily, in fact, than could a similar collection of the animals of the lake itself; yet this was the common and emphatic judgment of the whole aquarium force. Losses were generally heavy for a few days after the arrival of a consignment from the coast, but when those badly bruised and greatly weakened had died, the remainder usually lived surprisingly well. In the middle of the season, for example, during the three weeks from July 18 to August 8, only thirteen specimens died of the several hundreds in our salt-water collections at the time, viz: a sea-robin, six sheepshead, a small skate, a tautog, a flounder, a filefish, and two Pacific anemones; and a week of this period passed with the loss of only a single fish.

In this connection it should be remembered that the end toward which we were working, and the forced and hurried character of our operations, made it impossible for us to experiment with the various species coming to our nets, or to select to any considerable extent those known to be hardy in the aquarium. We were compelled to take our chances with everything not notoriously unfit for even temporary maintenance. With time, experience, and opportunity for methodical procedure, a marine aquarium collection could be gradually brought together in the interior which would far surpass in numbers, variety, and cheapness of maintenance that which we were able to hurry in pell-mell for a brief exposition season.

It seems not especially remarkable that the salt-water aquarium should prove, in the present state of our knowledge, much easier of maintenance than the fresh-water, since it has heretofore received by far the greater share of attention. Most of the great aquaria of the world have been either on the coast or in easy reach of the sea, and have contained marine animals chiefly, since these are, on the whole, much more varied, curious and beautiful, and also of greater scientific interest than those of fresh-water habit. Our own fresh-water collection, which usually contained over a hundred species, represented by two or three thousand specimens, was probably the largest ever maintained, and the previous experience of our aquarium superintendents having been chiefly with salt-water forms, the difficulties impending were not fully appreciated in advance. Our determination to be visibly ready May 1[*] forced us to do some things which would not have been admissible under other circumstances.

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[*] Two viviparous perch (*Micrometrus aggregatus*) of the Pacific coast, brought from Monterey June 20, gave birth July 9 to 17 young, which grew rapidly and were alive at the close of the exposition. A toadfish (*Batrachus tau*) spawned July 9, but the eggs did not hatch, probably for lack of fertilization. Mummichogs (*Fundulus heteroclitus*) and stickle-backs (*Apeltes quadracus*) also spawned in July, and a number of young hatched from their eggs were alive November 1. August 27, a skate's egg containing a young skate, still alive, was found in an aquarium tank with adult female skates. In September 5 whelks (*Sycotypus canaliculatus*) spawned, each requiring from 2 to 5 days to extrude its long string of large, tough egg-cases. Young anemones (*Metridium marginatum*), hatched after the arrival of the lot from Wood's Holl, were abundant in the anemone tank all summer, covering the rocks in hundreds. The fresh-water species spawning were the common sucker (May 4 to 20), golden ide (May), goldfish (June 16), pike perch (April 1 to 30), yellow perch (April 29 to May 9), rainbow trout (May 30), Von Behr trout (November 5), Mississippi catfish and blue sunfish (*Lepomis pallidus*).

The great obstacle to the successful and economic maintenance of a fresh-water aquarium is the liability of many species to parasitic disease, either that due to saprolegniaceous fungi (with which we were already very well acquainted)[†] or to that caused by a protozoan parasite not hitherto reported for this country, and but little known in the Old World.

Fungous parasitism began with especial virulence very early in the season—a fact to be attributed partly to the enforced hurry of our preparations, which made it impracticable to assort or quarantine our specimens as they came in, and partly to a delay in placing the filters, on which account we were obliged to keep our material for some weeks in unfiltered water.

The plant parasite causing this disease was carefully investigated at my instance by Mr. G. P. Clinton, assistant in the botanical department of the University of Illinois.[‡] Only one fungous form was found attacking the fish—probably the well-known *Saprolegnia ferax.* It was not, at the time of his visit, in a stage of development favorable to the precise determination of the species, and there is consequently some uncertainty with respect to its specific name. There is no doubt, however, that it belongs to the genus *Saprolegnia.* It appears in patches, large or small, either in the form of a grayish or whitish film (sometimes half fluid and sometimes resembling a thickish felt), or as a growth of delicate threads an eighth to half an inch in length, springing from the surface of the affected fish either in tufts or irregularly distributed. It takes its origin in every case in microscopic spores each provided with minute swimming hairs (flagella) by which they move freely through the water. These spores, matured by myriads in growing fungous threads, settle on excrement or dead animal matter in the tank, and may grow and multiply there as freely as on the fish.

Dead flies furnish an excellent nidus for the cultivation of this fungus, and the presence of the spores in the water may be very easily determined by simply dropping a dead fly into a bottle filled with the water to be tested. In this way we demonstrated the general infection of all the waters in and out of the aquarium. Every experiment tried with water from the lake, from the lagoon, and from the central pool in the aquarium building, and a large proportion also of those tried with vials of water from the aquaria and from the supply pipes inside, yielded cultures of this *Saprolegnia*.

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[*] All the tanks but two were occupied on "opening day," many of them to the limit of their capacity.

[†] In our efforts to control this fish-parasite, and in matters of aquarium management generally, I enjoyed the great advantage of the aid and advice of Dr. T. H. Bean, representative of the U. S. Fish Commission on the Government Board of Control. His long connection with the Commission in capacities which made him thoroughly acquainted with its aquarium methods, and his own experience while in charge of the aquarium exhibit of the Commission at the Cincinnati Exposition in 1888, made him an invaluable adviser in every emergency, and much of our success was due to his unfailing kindness and to his warm personal and official interest in aquarium affairs.

I take this occasion also to express my obligations to Mr. W. de C. Ravenel, chief special agent of the Commission, in general charge of its exhibit, for much valuable assistance and advice given in his capacity of administrative officer.

The aquarium was in immediate charge of Messrs. L. G. Harron and Alexander Jones, without whose expert skill and faithful service success would have been utterly impossible.

[‡] Mr. Clinton's report is presented as an appendix to this paper.

The principal safeguards and remedial measures against this fungous disease are (1) the original discrimination of susceptible from hardy species of fish, that each may receive its appropriate care and treatment; (2) the utmost care in the capture, handling, and transportation of fish intended for the aquarium, that they may arrive without bruises or loss of scales, and (even more important than this) without unnecessary weakening of their vitality; (3) the use of a large shallow pool as a temporary receptacle for new arrivals, where they may be kept under surveillance and under the most favorable conditions until any tendency to fungous disease may have declared itself; (4) the rejection, or at least the separate maintenance, of all injured specimens until death or complete recovery; (5) the maintenance of a hospital tank to which all individuals may be immediately removed for special care and treatment on the first appearance of fungous parasitism in any tank; (6) the use of open shallow tanks (in place of deep aquaria) with light-colored bottoms, freely exposed to sun and air, and the maintenance of a free and rapid flow of water through them; (7) the association in the same tank of fishes of different habit, but especially the distribution everywhere of suckers, buffalo, or other bottom feeders, which continually police the tanks by working over the bottom for particles of food; (8) the most scrupulous cleanliness in the management of the tanks, and care not to introduce a superabundance of food; (9) the thorough filtering of the water, preferably with the aid of alum so added that there shall be no excess remaining; (10) the prompt and thorough disinfection, by washing and soaking with a solution of carbolic acid, of every tank in which the fungus appears; (11) the use of a solution of salt or carbolic acid as a remedy for moderate cases of disease; and finally (12) an abundant food supply and expert care generally in the maintenance of the health and vigor of the fish. For this last purpose I am inclined to suggest the establishment of an exercise pool for the larger and more active species, especially the game fishes, which might thus be released occasionally from their cramped quarters in the aquarium and permitted to stretch their muscles in a good straight swim.

I hardly need say that in handling diseased specimens special nets should be used, which should then be considered as infected and should never be allowed to touch healthy fish or be put into the water with them until soaked in some disinfectant solution. I may add that the source of the water supply may easily have an important bearing on the liability to fungous disease. If derived from clean springs or wells, or perhaps even from clear running streams, the water will contain few or none of the spores of *Saprolegnia*, since this fungus grows normally and most abundantly on decaying organic substances. It would further seem a good general practice in establishing a fresh-water aquarium, to select only young or half-grown specimens as representatives of the more susceptible species, since these commonly resist the fungus far better than adults, and might be expected to become in time much better adapted to aquarium life.

Although there is a general impression that this fungous disease will not attack healthy fishes unless offered a starting-point in some surface injury, it is now certain that this is not true. The general current of our observation during the season leads to this conclusion, which has been amply confirmed by a special experiment arranged to test the possibility of protecting the more susceptible kinds by the nicest aquarium management. October 1 an expert botanist and bacteriologist, already mentioned, Mr. G. P. Clinton, of the University of Illinois, thoroughly disinfected, with a strong carbolic acid solution, an aquarium tank completely isolated with respect to water supply and overflow. In this tank was placed a collection of small-mouthed black bass which had been brought to the aquarium especially for this experiment. They had been taken in the seine, landed with the utmost care, borne in the hands to avoid surface injury, transported in an abundance of water, and were when put in the tank in perfect condition in every way. They received the best of care and treatment, but within two weeks the *Saprolegnia* appeared upon them, and before another week the whole lot was practically gone with fungous disease. It should be said that the aquarium filter was working badly at the time, and that more than the usual number of spores doubtless entered this tank.

As the most general result of our season's work and observations with respect to the relative susceptibility of the various species of fishes handled by us during the summer, it appeared that native vigor of constitution and adaptation to a life of confinement were the most important elements of a capacity to resist fungous attack. The spores sprout abundantly in the surface slime of fishes of every description, but their filaments seem to penetrate the skin of certain species only, and of many of these only under special conditions. The most susceptible fishes on the whole were the active game fishes, whose imprisonment in our small aquarium tanks seemed to work too great a change in their habit of life to keep them in perfect health. Among these it was not an uncommon thing for a considerable group to remain in a tank by themselves for a long time without the appearance of any fungous disease, but later to go almost all at once, as if they had finally succumbed through a gradual weakening of their vitality under their prison life. On the other hand, many kinds susceptible at first, and even seriously attacked, would rally presently, after they had become accustomed to confinement, and especially after they had begun to feed.

Among the most susceptible fishes were the large-mouthed black bass, crappies (both species, but especially the paler), the white bass, the yellow bass, the pike-perch, the yellow perch, and the tooth herring. The sand pike or so-called jack salmon was scarcely less liable to the disease, and the warmouth sunfish was also frequently attacked with fatal effect. The lake trout and grayling were occasionally killed by this fungus; the common pike became liable to it if left long in confinement; and the common species of redhorse, and the stone-roller, though lasting frequently for weeks, would eventually drop off one by one. The common sucker and the buffalo were rarely infested after they had begun to eat. The forked-tail cat, the mud cat, the common bullheads, and the marbled cat, rarely suffered at all; on the other hand, the yellow catfish (*Ameiurus natalis*) was often severely attacked. The sheepshead or white perch appeared usually somewhat delicate; but three specimens, among the earliest of our fishes to arrive, lived the whole season through. The spoonbill (*Polyodon*)—never before kept in an aquarium for any length of time—lived with us for months with an occasional appearance of saprolegniaceous fungus on bruised surfaces, especially at the tip of the snout, but perished, if at all, from lack of its native food, which is of a character not to be supplied to it in our tanks. Rock bass, trout, bream, and the sunfish species generally, except those already mentioned, were not often infested, although the bream and other sunfishes were likely to go one at a time, as they weakened individually. The European carp and the common ornamental fishes (golden ide, goldfish, and tench), thoroughly accustomed as they are to aquarium life, were scarcely affected at all; and the dogfish, the gars, the sturgeons, the striped sucker, the native species of carp, the burbot, the eel, and the lamprey were also practically free from disease. Whitefish, although living but a short time in the aquarium, were not particularly liable to the fungous disease, but seemingly died because they would not eat.

April 28, eighty-seven young catfish (*Ameiurus albidus*) about 6 inches long, just received from the Potomac River, were placed in an aquarium together. Their interesting habit of massing in the center of the tank, each one swimming slowly back and forth and in and out through the school, attracted common attention to them. About six weeks later it was noticed, however, that their habit had changed completely, and that they now scattered everywhere, swimming restlessly about day and night, as if eager to escape. At this time it was also observed that the skin of these fish was covered with minute white specks, that they had ceased to feed, and were beginning to die. The usual aquarium treatment for fungous disease was tried without special result, and as other species near them in the aquarium had become similarly affected, I began, July 10, a preliminary microscopic and experimental study of their disease. The minute pimple-like specks on the skin, on the gills, and within the mouth were found to contain large, spherical, densely ciliate protozoa. These were contained in little cavities in the epidermal layer of the skin or mucous membrane, within which they kept up an incessant rolling motion. If freed from their confinement they swam about rapidly through the water, where they could be readily seen with the naked eye.

I soon ascertained that this parasite belonged to the genus *Ichthyophthirius* of Fouquet,* first described in Europe in 1869, and recorded there as an aquarium parasite especially destructive to young trout, but infesting a number of other species also. As the practical problem pressed upon us much more urgently than the scientific one, we began without delay a series of experiments with vinegar, salt water, copperas, carbolic acid, and other like substances, hoping to find some disinfectant solution in which the infested fish might be dipped with the effect of killing the parasite without injuring the fish. Time failing for the active and continuous work which the subject demanded, I had the good fortune to secure the assistance of Dr. Charles W. Stiles, of the Department of Agriculture, who was at the Exposition at the time. By courtesy of Hon. J. Sterling Morton, Secretary of the Department of Agriculture, Dr. Stiles was given leave of absence, and July 17 entered on a systematic experimental investigation of the subject. The report which he has filed for publication with this paper makes unnecessary any further account of the matter here.

I will only add that no disinfectant substances were found practically useful. Salt was the only one even recommended to us as the result of Dr. Stiles's experiments, and if this were employed to the extent necessary to destroy the parasite, it commonly affected the fish more injuriously than did the parasite itself.

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* See *Infusionsthiere als Hautparasiten bei Süsswasserfischen*, by F. Hilgendorf and A. Paulicki, (Centralbl. f. d. med. Wissensch. 1869, p. 33); *Note sur une espèce d'infusoires, parasites des poissons d'eau douce*, by D. Fouquet (Arch. zool. exper., t. v, 1876, p. 159); *Chromatophagus parasiticus n. g. et n. sp. Ein Beitrag zur Parasitenlehre*, by C. Kerbert (Nederl. Tijdschr. v. d. Dierk. Jahrg., v., 1884, p. 44); "Manual of Infusoria," p. 530, by W. S. Kent; Bronn's "Thier-Reichs" Bd. I, III. Abth., p. 1678; and *Ein infusorieller Hauptparasit bei Süsswasserfischen*, by O. Zacharias (Biol. Cent. 1893, p. 23).

The diseased fish could not eat, but rejected their food as if their mouths were sore, and their respiration was seriously affected by the inflammation of the mucous membrane of the gills. These difficulties, added to a general irritation of the skin, shown by the restlessness of the fish and by their disposition to scratch themselves in the sand, seem quite sufficient to account for our heavy losses among infested fish. The trout exhibit was very nearly destroyed for a time, and several other species were almost equally infested, but with quite various effect. The season's experience confirmed the conclusions of Kerbert that this is a hot-weather parasite, since it disappeared almost entirely from the aquarium during the month of September, as the temperature of the water fell off. It is thus very likely to affect most injuriously species which are most sensitive to the heat. The thickness of the skin seemed also to modify greatly the effects of an attack; and this is perhaps the reason why young fish are much more likely to succumb than old. Young catfish died like sheep with the murrain,* but adults of the same species would become gray with pimples without apparent suffering, and presently become clear again. Wild brook trout, brought in from the streams, proved much more hardy under this disease than tame-bred specimens, but all recovered as the weather cooled.

We have no reason to suppose that this parasite is common under natural conditions, and do not know, in fact, that it was brought into the aquarium more than once. It would seem, therefore, that its ravages might be held in check by a prompt recognition of it on its first appearance, and the complete isolation, or perhaps the immediate destruction, of infested fish. Certainly nothing should be allowed to go into an uninfested tank which has been in any sort of contact with an infested one. The best remedial measure known to us is a constant and very abundant flow of the clearest water obtainable. This seems not only to check the development of the parasite, but also sweeps off those which escape from the tissues of the infested fish previous to reproduction, and so reduces the probability of repeated infection.

If I were again to experiment with remedies for this disease, I would construct a hospital tank with hard bottom and smooth vertical sides, and with a second bottom, say, 6 inches above the other, made of wire netting with meshes just small enough to prevent the passage of fish. In this tank I would put salt so freely as to keep a layer of dense salt water in the bottom of the tank the greater part of the time, but not so freely as to render the water above the screen injurious to fresh-water fish. As the parasite leaves the fish and sinks to the bottom, losing its power of locomotion before dividing to give origin to young, and as when naked it is very readily killed by salt, I should thus expect to prevent its multiplication in the tank, and should hope that the fish infested might presently clear themselves spontaneously. An occasional dip of the fish in a salt-water bath would probably be an aid to recovery.

From the foregoing it will be seen that the greatest present problems of aquarium management are those connected with the maintenance in confinement of fresh-water fish. I have only to hope that this frank statement of my experience with the exposition aquarium of the U. S. Fish Commission may contribute to the solution of these problems, and help to make more easily possible to the American public a real knowledge of the aquatic life of this country.

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*One hundred and fourteen young spotted catfish, 5 or 6 inches long, were taken out of a single tank July 28, dead over night with this disease.

DESCRIPTION OF THE FRESH AND SALT WATER SUPPLY AND PUMPING PLANTS USED FOR THE AQUARIUM.

BY I. S. K. REEVES,

Passed Assistant Engineer U. S. Navy.

Fresh-water supply.—The water for the fresh-water aquaria was supplied from one of the water mains under the aquarium building at an average pressure of about 60 pounds per square inch, and before passing into the supply pipes erected over the aquarium this water was filtered by two pressure filters of the Jewell patent, having a rated guaranteed capacity for filtering 125,000 gallons of water each in twenty-four hours. After the water had been filtered it passed through the galvanized iron supply pipes which were erected above the aquaria and into which were screwed brass jet cocks, through which the delivery of the water for the aquaria was regulated.

Each aquarium had an overflow or waste pipe that was so arranged that the surplus water was allowed to discharge into a waste pipe which emptied into the lake, and by this method the water was being constantly changed in the aquaria. The piping, valves, fittings, etc., in connection with this system were either of galvanized iron or brass.

Pumps and electric motors.—There were two independent reciprocating direct-acting geared force pumps with water ends of hard rubber, having a capacity of about 4,000 gallons of water per hour each at 90 strokes per minute.

They were driven by belts from a counter shaft that was driven by two electric motors of about 6 horse-power each, at a speed of about 1,500 revolutions per minute. The current for these electric motors was about 500 volts.

The pumps were so arranged that one or both could, if necessary, deliver their water direct into the main supply pipe for the aquaria.

The pumps and electric motors were located in a separate room under the floor of the main building of the Fisheries Exhibit near the salt-water reservoir from which they obtained their water.

Salt-water reservoir.—There was located under the floor of the main building of the Fisheries Exhibit a reservoir constructed of brick and Portland cement, with a capacity of about 68,000 gallons. The bottom of the reservoir was of concrete and the surface of asphalt.

Distributing tank.—There was located in the top, under the roof of the main building of the Fisheries Exhibit, about 54 feet above the aquaria, a cylindrical wooden distributing tank having a capacity of about 2,500 gallons, into which the pumps delivered their water through hard-rubber piping.

The distributing tank was connected to the salt-water reservoir by an overflow pipe of hard rubber.

Filters for salt water.—There were located under the floor of the main building of the Fisheries Exhibit two pressure filters of the Jewell patent, each 6 feet in diameter, 5 feet in height, connected to operate independently or together. The rated guaranteed capacity of these two filters was 250,000 gallons in 24 hours.

During the first month or two of the Exposition it was not found necessary to work the filters to their rated capacity, but during warm weather they were frequently worked beyond this capacity. The rate of filtration at some periods was as high as 750,000 gallons per day, and although the filters were taxed to this great extent their work was satisfactory.

The filters worked under a pressure ot 60 pounds to the square inch in the inlet, and from 50 to 60 pounds in the discharge pipe; the difference in the pressures varying according to the time the filters were in operation between washing, or in other words with the accumulation of the impurities.

The filter beds were composed of white machine-crushed quartz, and were 2 feet 4 inches in depth.

The water before it entered the filters was treated by the addition of a very small quantity of alum solution. The amount of alum used averaged about $\frac{1}{5}$ of a grain per gallon, or 1 pound for about every 30,000 gallons of water filtered. The expense of this alum was about 2 cents per pound.

The action of the alum upon the water was a chemical one, and served to remove the dissolved-coloring matters and invisible impurities, such as bacteria, etc., and it also served to assist the retention of the extremely fine particles of suspended matters, which would otherwise pass through a filtering bed of the nature and porosity of that which was used in the filters during a high rate of filtration.

Analysis demonstrated that not the slightest trace of alum that passed through the filters appeared in the filtered water. The apparatus used for introducing this solution of alum was located about 150 feet from the filters on the inlet pipe, and was exclusively an auxiliary apparatus.

There were also located under the floor of the arcade, at the end nearest the aquaria, two box filters, 12 feet long, 4 feet wide, and 2 feet deep, constructed of 2-inch plank. These were filled with layers of coarse gravel and fine sand, through which all the waste water from the aquaria was filtered before passing to the main reservoir.

Apparatus for regulating the temperature of the fresh and salt water supplies.—For the purpose of regulating the temperature of the water for the aquaria in summer and winter, there were secured to the joists under the arcade two sections of 12-inch wrought iron pipe, each 20 feet long, and on the ends of each section were screwed cast iron caps. One of the caps on each section had two holes drilled in, to allow $2\frac{1}{2}$ inch pipes to pass through.

The section of 12-inch pipe used for the salt water contained four lengths of drawn brass pipe, $2\frac{1}{2}$ inches diameter and 20 feet long, tinned inside. These four lengths of pipe were so connected as to form a continuous coil. The ends of these coils passed through holes in one of the caps of each section, and were fitted with inside and outside lock nuts, thus making the sections or reservoirs steam and water tight.

These coils were afterwards connected, by proper valves, to the supply pipes to aquaria, and were so arranged that the supply water for the aquaria could be made to pass through these coils if necessary.

The section of pipe and its coil which was used for the fresh water was similar in construction to that used for salt water, except that the coil was made of galvanized-iron pipe instead of brass.

The coil of this section was connected to the fresh-water supply pipe of the fresh-water aquaria between the Jewell filters and fresh-water aquaria, and so arranged that the fresh water could be made to pass through the coil or pass direct to the aquaria.

These sections of 12-inch pipe were connected to a steam boiler located under the aquaria building, so that steam could be introduced into them and around the coils; in this way the fresh and salt water supplies to aquaria could be raised to the temperature desired.

In order to regulate the temperature of the salt-water supply for aquaria during the warm weather, the section of 12-inch pipe containing the brass coil was connected to the fresh-water supply pipe between the water main and the Jewell filters, and was so arranged that a continual flow of fresh water could be introduced into the 12-inch section and around the coil through which the salt water was passing; the fresh water being at a lower temperature than the salt water, it was used as a medium during the hot weather to cool the salt water supply to aquaria.

Salt-water pipe, pumps, etc.—All piping, parts of pumps, valves, jet cocks, etc., in contact with the salt water were made of hard rubber, with the exception of the drawn brass coil, described above, tinned inside in the section of 12-inch iron pipe, which was used to regulate the temperature of salt-water supply.

Operation of salt-water plant.—The pumps having separate suction and delivery pipes and run by separate motors, each pump was independent of the other and interchangeable, making two separate and distinct plants; and in case of accident to one pump or motor or of any of its attachments, the other pump was capable of supplying enough water for the aquaria. It was not found necessary at any time to run both pumps at once.

The water was drawn from the reservoir by the pumps through hard-rubber pipes and pumped into the distributing tank. From the distributing tank the water was conveyed by gravity through hard-rubber pipes to the apparatus for regulating the temperature, and into the supply pipes located over the aquaria. From this supply pipe it was delivered through jet cocks into the aquaria.

The overflow or waste water from the aquaria passed into the box filter filled with sand and gravel, and from them through hard-rubber piping to the main reservoir.

Air circulation for salt-water aquaria.—The Bishop and Babcock Company of Cleveland, Ohio, courteously lent the U. S. Fish Commission two of their hydraulic pumps, which were operated by water taken from the fresh-water main, and it was found that one of the pumps having 3⅜-inch diameter water cylinder, 5¼-inch diameter air cylinder, and 8-inch stroke, would furnish sufficient air, at a pressure of 7 pounds per square inch, to aërate all the salt-water aquaria.

The air pumps delivered the air into a galvanized air cylinder at a pressure of about 7 pounds per square inch. From this receiver the air was conveyed to the backs of each salt-water aquarium by iron piping, and there connected with each aquarium by rubber tubing, into which were inserted wooden liberators through which the air was forced into the water.

OBSERVATIONS AND EXPERIMENTS ON SAPROLEGNIA INFESTING FISH.

BY G. P. CLINTON, B. S.,
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The fresh-water fish in the aquarium of the U. S. Fish Commission at the World's Fair having been more or less troubled by a fungous disease, the writer was asked in October to make a study of the same. A glance in the microscope at material taken from a diseased fish was sufficient to determine that a common fish-pest, *Saprolegnia*, was at work; but as it was not present in its mature stage, further study, including culture experiments, was undertaken.

The fresh-water fish occupied twenty-eight tanks, just within the wall of the circular room, and also a number of larger tanks, separated from the former by a wide aisle. In the center of the room a large circular basin was also given up to them. The water was supplied by way of a crib a few miles out in Lake Michigan, and after having its solid matter precipitated by alum and passing through a sand filter it escaped in several small jets into the individual tanks, entering with sufficient force to carry down air bubbles from one to two feet. The water passed off by an overflow at the top, and was not used again, but drained into the lake. The tanks were emptied once or twice a week and cleaned, while the central basin was run down every night and refilled. It was in certain of the smaller tanks that the disease was worst. The fish were brought to the aquarium in the cars of the U. S. Fish Commission, chiefly from the Great Lakes and from streams of the Mississippi Valley or from breeding stations of the Commission. They were carried in water cooled by ice, but the transfer to the aquarium was so managed that the temperature was gradually raised before they were placed in the various tanks.

According to the statement of the assistant in charge, the fish never showed signs of disease when they arrived. There were no means of regulating the temperature of the water in the aquarium, and at the higher degrees (68° to 74° F.) the development of the fungus seemed to be considerably stimulated. The fish were fed corn bread, liver, beef, or minnows, according to species.

The fungus developed on all parts of the fish, though perhaps more abundantly or more frequently on the tail, fins, or head. According to the host or stage of infection, it would be limited to small, definite patches, or spread all over the fish. In general it formed a tuft of white threads that radiated out from the body a distance of about a third to half an inch. While a fish might be abundantly covered with the fungus, so that in water the threads would float out in a radiating mass, when the fish was removed from the water the threads, too weak to support themselves erect, would collapse, and the fish would then present a slimy appearance, and would not seem so badly infested. In those that were but slightly attacked the fungus was, as a rule, more definitely limited to spots on different parts of the body. Usually in such cases it was developed as a bunch of filaments on some bruised place. Occasionally fish could be found on which the fungus had grown as a mass of filaments covering the eyes and causing blindness. Sometimes the tail and fins had become so lacerated, at least in part by the action of this fungus, as to be almost destroyed. If new arrivals were affected, it was usually within a week after they were placed in the aquarium that they began to show the disease plainly. Within three or four days of its beginning the surface would become abnormally slimy, when an examination of the epithelial débris, covering the fish, would reveal the presence of numerous prostrate filaments of the fungus imbedded in this material. From these the erect radiating filaments were rapidly produced, so that in a few days fully developed zoösporangia could be found.

There is no doubt that this fungus was primarily a saprophyte, as are most of its family, and that its parasitic habit is a secondary acquirement. It now acts in either capacity, as opportunity offers. Probably the abundance of slime on some kinds of fish has much to do with the fact that the fungus obtains its first hold on them. If the fish is not protected by well-developed scales, or an unusually thick skin, it is especially at the mercy of its invader. Having gained entrance, the fungus makes its presence manifest by causing local irritation. The blood can sometimes be seen in reddish patches in and about the part affected, and the fish frequently shows a desire to scratch the injured spot by rubbing against some object or scrubbing itself in the sand on the bottom of its tank. In a more advanced stage the fish becomes sluggish and frequently dies, when a vigorous growth of the fungus follows until bacteria put a stop to it by causing putrefaction of the body. Often a badly infested fish will recover, and minor attacks come and go quite frequently among the more hardy species.

None of the marine animals in the aquarium were attacked by this fungous disease. In the fresh-water section a genus closely allied to *Saprolegnia* (*Achlya*) was found developed considerably on the eggs of a crayfish as they were attached to the parent. Some of the turtles were said to be "fungused," but no examination was made of material from this source. The growth on all the fresh-water fish seemed to be the same, and in all cases a *Saprolegnia*. There was a difference as to susceptibility, this apparently depending to some extent on the age of the fish or the species. Young fish seemed comparatively exempt from the disease. If one died and remained in the water it readily became covered with the fungus, but while living they were not much affected. This was true even of the same species in different stages of development. For example, a tank of young black bass showed no signs of disease, while mature fish of that species almost invariably "fungused."

Among the mature species there likewise seemed to be a wide difference in the power of resisting infection. Undoubtedly such factors as bruises, rubbed scales, changed and unusual surroundings, or insufficiently developed epidermal protection had much to do in determining liability to infection. For instance, fish with a tough skin, as the Mississippi catfish, or with a development of prickly and bony plates like the sturgeon, were usually free from the disease, while such as sunfish and black bass were quite badly affected. Certain species, as the goldfish, which have been reported in other places as sometimes becoming infected, escaped here, giving no evidence of the disease. It is also a fact that all those foreign fish that were bred by the Fish Commission, and that are commonly cultivated as aquarium fish, such as the goldfish, already mentioned, golden ide, and tench, escaped entirely, while native fish recently collected from streams, etc., were quite apt to become infected unless well provided with resisting epidermal parts. Daily examination of the aquaria during a period of three weeks showed that at that time sturgeon, burbot, mud catfish, Mississippi catfish, carp (American, scale, mirror, and leather), tench, goldfish, golden ide, *young* trout (brook, Von Behr, and Loch Leven), and *young* black bass were practically free from attack; that small-mouthed black bass, rock-bass, brook trout (adults), yellow catfish, spotted catfish, buffalo, dogfish, paddle-fish, moon-eye, the long-nosed and short-nosed gar, the redhorse, and the common suckers were somewhat affected, often but slightly and usually in bruised places; and that the black bass (*adult*), white bass, yellow bass, calico bass, yellow perch, grayling, pike, pike perch, sheepshead, sand pike, bream, blue sunfish, warmouth, and individual cases of the sucker and redhorse were badly diseased.

It has long been known that dead insects falling into water are quite likely to have developed on them a growth of the species of fungi under discussion,* and botanists have taken advantage of this fact for the development of these fungi, placing insects in water likely to contain such forms, or inoculating insects and then placing them in pure water. In such cases, in a few days, a vigorous growth of fungous filaments radiates from the insect on all sides, and the appearance and development of the fungus can be studied as desired. The only drawback to such cultures is that bacteria are likely to develop on the dead insect, and after a time seriously interfere with the growth of the fungus; but, wishing to make a study of the water, such cultures were undertaken. As the fungus developed abundantly on the liver fed to the fish, if it remained a few days in the water, this was first used for culture experiments, but bacteria were developed in such numbers on the meat that it was found useless, and flies —the only insects to be had—were resorted to with fairly good results. It was desired to test the water immediately before its entrance to the tanks, in order to learn if the germs were then present; to test it in the different tanks, and in various parts of the same tank, to ascertain if the germs were present or absent, or relatively more or less abundant in the different situations; and, lastly, to determine if different fungous forms existed in the water taken from these various places. An examination of water taken directly from the lake and of the hygeia water used for drinking purposes on the Exposition grounds, was also made.

The method pursued was as follows: A small bottle of the water to be tested was taken and a fly or two dropped in it and left for twenty-four hours—a sufficient time for the infection of the fly if fungous germs were present—when the water was replaced by that known to be pure. Twenty-four hours later, if the culture was successful, a slight growth of the fungus could be seen radiating from the insect, and one or two days thereafter the zoösporangia began to form. After the expiration of a week,

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*Ledermüller, *Mikroskopische Ergötzungen*, 1760.

further growth in length was not noticed. The filaments usually reached a length of a third to half an inch. In ten days or two weeks further development was usually stopped by bacteria. No cultures being successful in the hygeia water, it was regarded as pure and used to place the flies in after their inoculation.

At first no cultures were obtained from water taken just before its entrance into the various tanks of the aquarium, and it was thought to be free from the fungus, but as more were attempted an occasional growth of *Saprolegnia* appeared, quite similar to that found on the fish. About a third of the tests of water from this source gave cultures—a proportion large enough to indicate that the water supply may have been the original source of infection. The fact that cultures were thus occasionally obtained from the water just before it entered the tanks was probably due to the imperfect working of the filter system, which was sometimes out of order, the water in the tanks then becoming quite turbid. It was said that the clearness of the water was similarly affected when the lake was especially rough. When the fungus had once obtained a foothold in the tanks it became, of course, much more abundant in its spore forms. Cultures obtained from water from the lagoon and from the edge of the lake yielded in every case some form of *Saprolegniaceæ*.

There was some slight difference in the number of successful cultures in water taken from the various tanks. For example, growths were almost invariably obtained from those tanks that contained infected fish, while water from tanks in which the fish were not diseased yielded cultures in scarcely more than half the cases.

Another difference was found in the character of the growths. While on the fish themselves nothing but a species of *Saprolegnia* was found, in water cultures from the different tanks three genera were encountered; viz., *Saprolegnia*, *Achlya*, and *Leptomitus*. The *Leptomitus* was found only as a secondary product in a few impure cultures that were not well developed. Pure cultures of either the *Saprolegnia* or the *Achlya* were usually obtained, but occasionally a growth was found in which they both occurred. Still another distinction was noted: The water cultures from aquaria containing badly "fungused" fish almost invariably gave *Saprolegnia*—commonly a pure growth; those from aquaria in which the fish were healthy, generally gave *Achlya*; while those from tanks in which the fish were slightly affected by the disease yielded either *Achlya* or *Saprolegnia* or an impure growth of both. The *Achlya* and *Saprolegnia* cultures could be readily distinguished even with the naked eye. The former had the longer filaments, and the bunch of zoöspores clustered at the opening of the emptied zoösporangia could easily be seen. In cultures of the *Saprolegnia* the filaments formed a rather dense growth which radiated from the fly for about a third of an inch. When the zoösporangia began to form, the threads became more opaque at their free ends.

The tests of water taken from the tanks at various depths gave us no differential results. It seemed to make no essential difference in the character of the growths whether the water came from the top, the center, or the bottom of a tank.

Numerous experiments were made by placing a little of the fungus taken from diseased fish on flies in hygeia water. These cultures were always successful, and, so far as one could judge from the asexual stage, were of the same species as those obtained from the water cultures which gave growths of *Saprolegnia*.

Altogether, something over 100 cultures with flies were made, but in none of those which yielded the *Saprolegnia*, and in none of the numerous specimens examined from the fish, were there any signs of the mature stage of the fungus. In the *Achlya* cultures, however, this stage was reached occasionally. When the cultures of *Saprolegnia* were about ten days old, further development being prevented by bacteria, the production of the normal zoösporangia was arrested, and what are known as "resting sporangia" were formed. These were produced, in a moniliform manner, by the constriction of the filaments into one or several cells in which the protoplasm was not differentiated into zoöspores, and which were somewhat shorter in comparison to their breadth than were the usual zoösporangia. The results of most of the cultures that were made with flies are given below:

Tabulated results of culture experiments.

Sources of infection.	Successful.	Failed.
Aquarium water	5	10
Hygeia water	....	6
Lake Michigan water	3	....
Lagoon water	2	....
Central Pool water	4	....
Fungous inoculations	15	....
Water from experiment tank	2	2
Water from tank containing badly diseased fish:		
Top	6	1
Center	2	....
Bottom	6	....
Bottom stirred	3	1
Water from tank containing fish but little diseased:		
Top	1	1
Center	1	....
Bottom stirred	1	....
Water from tank containing healthy fish:		
Top	3	2
Center	1	3
Bottom	4	1
Bottom stirred	2	1

The minute structure and life-history of such fungous forms have been so thoroughly made out by eminent specialists that no investigation along this line was made, save to observe those phenomena which might be easily seen with ordinary microscopic manipulations. The fungus consists of branched, hyaline filaments, without septa, except as these are found cutting off the reproductive parts of the threads. It is made up of a root-like or rhizoid part that penetrates the fish, and a vegetative and reproductive part that radiates from the host. The former consists of branched tapering threads which pierce the tissues for a short distance, but are easily pulled out. The function of this part is to obtain nourishment for the growth of the external parts. Prostrate threads are found running through the natural slime covering the fish, and from these are produced the erect radiating hyphæ so plainly seen when in the water. The development of these threads appears to be very rapid when viewed under the microscope, although the growth made under favorable conditions in two days is only about a third of an inch. From actual measurements of filaments of the fungus placed in water and watched under the microscope, it was found that certain threads made a growth of about 300 microns in an hour. Two others, watched for twenty minutes, gave in that time a growth of 90 and 47 microns respectively; and yet another filament, observed during two periods of five minutes each, made a growth of 28 microns each time. In ordinary cultures the rate of growth depends upon the condition of the medium, host, etc.

The first evident sign of a spore stage is when the filaments, having reached a certain length, become more or less clavate at their free ends. It is then noticed that the protoplasm is much more abundant here. A constant circulation of granules in the protoplasm is going on, and the small nuclei are seen gradually moving along the cell wall toward the end of the filament. A band of protoplasm, free from granules, is next formed at the lower end of the clavate part of the thread, and across the lower side of this is rapidly developed a horizontal septum shutting off the club-shaped part of the hypha. Within this cell is now seen a shifting of protoplasm, with an appearance and disappearance of vacuoles. The septum has in the meantime become slightly convex downward, and the hyaline band has again become granular. When this shifting movement has continued for some time, the protoplasm is seen to form gradually into spore-like masses thickly crowded together and lining the cell wall. These become less distinct at times, and at last seem to lose their identity entirely. In the meantime a short papilla has been forming on the end of the cell, and the septum becomes convex upward. The spores again become distinct, though crowded closely together, and suddenly those near the papilla are seen to be forced into it and pressed against the wall, which is quickly ruptured. The zoöspores now rush out through the ruptured place, and soon swim out of sight; but all may not succeed in escaping from the zoösporangium.

Their form is ovate to oblong-ovate, with two cilia on the smaller hyaline end. By the lashing of these they keep up a rapid movement for some five or ten minutes, when, in the majority of cases, this ciliary motion gradually lessens and finally stops. Assuming now a spherical shape, the spore loses its cilia and secretes a cell wall. In some cases, however, those zoöspores which failed to escape from the zoösporangium were seen to move around for nearly an hour before becoming quiet. These spores while motile are without a proper cell wall, and frequently slightly change their shape. In the meantime the septum at the bottom of the zoösporangium becomes greatly convex upward, and a new growth of the filament takes place within the wall of the empty zoösporangium, this in time giving rise to another zoösporangium.

The zoöspores, after a short period of rest, are said to go through a second swarming, and then become stationary, as before. Soon after this second swarming the true germination of the spore takes place. This begins with a slight distention of the spore on one side. This distended part gradually becomes elongated, and is then seen as a germ-tube proceeding from the side of the spore. The growth of this tube is very rapid, although less so than that of the filaments of the fungus, being slowest while the tube is getting a good start and, at the last, when the protoplasm is about exhausted, but otherwise nearly uniform. The germ-tube tends to be bent or flexuous rather than perfectly straight. After it has made a slight growth vacuoles or rifts begin to appear in the protoplasm of the spore. These widen as the contents are gradually drawn into the tube, until the spore is entirely emptied. One germ-tube was observed that had reached a length of 145 microns before the germination had entirely ceased. These germ-tubes are without septa or branches, and each spore forms but one such tube. Spores germinated in water made a growth of the germ-tube equal to about 1 micron each minute during the time observed. The rate of growth of three different spores was respectively as follows: 45 μ in 45 minutes; 15 μ in 20 minutes; and 42 μ in 32 minutes.

It is by the germination of these zoöspores that the fungus chiefly propagates itself. They are asexual and short-lived, but are continually produced in enormous numbers, and are easily carried to their hosts by means of their cilia. The double swarming also favors distribution, and thus tends to render infection more probable. The fungus gains entrance to its host by its germ-tubes, which pierce the tissue.

Besides the zoösporangia with their zoöspores, the *Saprolegniaceæ* have another reproductive stage, consisting of antheridia and oögonia, the mature spore form of these being the oöspore. In the fungus studied these were never found. They are quite apt, however, to be produced less abundantly than the zoösporangia and zoöspores, even rarely, according to some authors,* and at special seasons only. While the generic distinctions of this group of fungi are based mostly on the characters of zoösporangia and zoöspores, the classification of the species depends almost entirely on the character of the antheridia, oögonia, and oöspores. It was impossible, therefore, to determine exactly the species to which this fungus belongs.

Enough was seen, however, to show that it belonged to what was indiscriminately called *Saprolegnia ferax* before De Bary's system of classification was proposed. By this author, however, *S. ferax* is divided into several distinct species, and with one of these, *S. mixta* (as described by Fischer in Rabenhorst's *Kryptogamen-Flora*), the fungus in question seemed most nearly to agree. During November it was said that a decided change in the appearance of the fungus on affected fish took place. Perhaps if material could have been then obtained, the mature form might have been found.

In the cultures made a parasite frequently appeared upon the fungus itself. This was what Cornu first called *Olpidiopsis saprolegniæ*. It belongs to the same great group (*Phycomycetes*) as does the *Saprolegnia*. It consisted of oval sporangia developed in the spherically-enlarged ends of the *Saprolegnia* filaments. The zoösporangium formed a short tube, which pierced the wall of the host filament, and it was through this that the numerous small zoöspores escaped. This parasite so enlarged the ends of the filaments it occupied as to make them visible to the naked eye.

The development of the fungus was of such a character as to render it a serious pest in the aquarium, and various efforts were made by those in charge to lessen its ravages. The tanks were drawn down once or twice a week, but this did not diminish the disease to any great extent. The standard remedy—salt—placed in the bottom of the tanks seemed to lessen the disease, and baths of salt water improved the appearance of the fish, destroying the fungus to some extent. Experiments were tried to determine the effect of salt water of different degrees of density on cultures of the fungus. The ordinary sea water of the aquarium was strong enough to cause a shrinking and collapsing of the protoplasmic lining of the fungous filaments soon after these were placed in it. Cultures on flies also failed to develop when placed in this water even when considerably diluted; but in one part of sea water to five parts of fresh a vigorous growth of the inoculated fungus was once obtained.

No special care had been taken to isolate healthy fish as they were brought in and it was suggested that this measure was worth a trial, notwithstanding the fact that an occasional culture had been obtained from the filtered water just before its entrance into the tanks. A tank was consequently selected, emptied, and thoroughly scrubbed throughout, and washed all over with a four per cent solution of carbolic acid. It was then rinsed with fresh aquarium water and emptied, after which it was filled with this water which was left running in the ordinary way for about a week, care being taken to dip nothing into the tank. A few days after the tank had been cleaned the filter seemed to work imperfectly, the water in all the tanks becoming cloudy. The fish selected for this special tank was the small-mouthed black bass, a species which had "fungused" somewhat readily. Twenty-three of the best specimens of a car-load were selected and placed in the prepared tank, the remainder of the lot being placed with fish that were more or less infected. None of the fish showed signs of the disease when taken from the car. Cultures made from water taken from the tank just after it was cleaned gave a very slight growth. Water taken from the tank the fifth day after cleaning gave no growth, while other cultures attempted in the filtered water, both before and after its entrance into the tank after the fish were placed in the tank, once gave *Saprolegnia* and once failed. This would seem to indicate that the zoöspores were present in the water, though in comparatively small numbers. As the tank was so thoroughly cleaned, the only possible source of infection in this case was the water supply. Four days after the fish were placed in the tank they began to have the very slimy appearance that accompanies the first stage of the fungous attack, and an examination of this slime showed that fungous threads were present, though not yet abundant. The bass that were placed with diseased fish seemed but little more parasitized, but later both lots became badly diseased, and in a fortnight were practically all gone.

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*Walpole and Huxley, in Twenty-first Report Inspectors of Fisheries, England and Wales.

The above experiment and the cultures made from the aquarium water before its entrance into the tanks show clearly that the original source of infection was the water supply—a difficulty it would seem impossible to remedy, at least with an imperfect action of the filter.*

It has long been known that species of *Saprolegnia* are sometimes found as parasites on aquatic animals. They are closely related in their structure to certain algae, and may be regarded as degenerated forms, which, because of their saprophytic or parasitic habits, have lost their chlorophyll. We are indebted to such investigators as Cornu, Pringsheim, and De Bary for much of our knowledge of the life-histories of these forms. Concerning the fungus most frequently found as a parasite on fish, English and Scotch writers seem to have written most, a fact due perhaps to the great outbreaks of the disease among the fish in the rivers of Great Britain in the years 1877 to 1880, during which time the loss was so great as to seriously interfere with the fisheries industry. Many kinds of fish were affected, but the salmon most disastrously. About the same time certain authors note an unusual occurrence of the disease among the fish of some of the rivers of this country.

Our American botanists have done comparatively little with this class of fungi. The most elaborate work is a monograph by Humphrey, treating of American forms, and giving the general life-history and the literature of this group. Hine (1878) published a general article on this class of fungi, and Galloway (1891) has dealt with the life-history of *Saprolegnia monoica*. Gerard (1878) and Lockwood (1890) have published articles treating of the special fungus of fish called by them *S. ferax*; otherwise—if we except the articles copied in American publications from foreign sources—our literature on the subject seems to be limited to mere references to *S. ferax* as a parasite of fish in certain places.

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*This filter was heavily overtaxed at the time, usually filtering more than twice the amount of water for which it was intended.

LITERATURE.

Perhaps no class of fungi has been more thoroughly studied than the *Saprolegniaceæ*, owing, no doubt, to the ease with which these forms may be observed through all their various stages of development. This has given rise to a very extended literature of the subject, and I append references to all items accessible to me in which *Saprolegnia* is mentioned as a parasite of fish. The name of the article is not usually given, but the reader is cited directly to the page on which mention of *Saprolegnia* occurs, and for convenience the character of the reference is briefly indicated.

Baron de la Valette St. George, 1879. Circular No. 3, German Fishery Association. (Translated by Jacobsen, in Rep. U. S. Fish Comm. for 1878, p. 509.)

Among enemies of fish mentions *S. ferax* as destructive to eggs and even live fish. Recommends a continuous supply of pure cold water.

Bencke, 1885. *Feinde der Teichwirtschaft*, in "Die Teichwirtschaft." (Translated by Jacobsen, in Bull. U. S. Fish. Comm., VI, p. 342.)

Refers to a saprolegnious disease of fish in central Europe, and says it may be cured by placing the fish in a 1 per cent. solution of salt water, or by washing them with still salter water.

Bennett, 1842. Parasitic Fungi in Living Animals. Trans. Roy. Soc. Edinburgh, vol. XV, pt. II, pp. 284, 287; also as separate.

Gives account of "colorless confervæ" found by different authors on fish and their eggs.

Berkeley, 1864. Intellectual Observer, p. 147.

Mentions certain *Saprolegniaceæ* as destructive to fish and their ova.

Berlese and De Toni, 1888. Saccardo's Sylloge Fungorum, vol. VII, pt. I, p. 270.

Mentions *S. ferax* as found on dead flies, fish, salamanders, etc.

Bessey, 1885. Botany for High Schools and Colleges, p. 257.

Notes *S. ferax* as growing on dead and living fish, and refers to the epidemic in England in 1878.

Botanische Zeitung, 1868, p. 829.

A short note in which Cohn is said to have produced death of goldfish by artificial infection with *Achlya*.

Brook, 1879. Trans. and Proc. Bot. Soc. Edinburgh, vol. XIII, p. 389.

Gives notes on salmon disease of the Esk and Eden rivers.

Buckland, Walpole, and Young, 1880. Report on disease which has recently prevailed among salmon.

Treats of *Saprolegnia*.

Century Dictionary, 1891, vol. V, pp. 5315, 5340.

Under "salmon-disease," and under "*Saprolegnia*," mention of *S. ferax* as destructive to fish, especially salmon.

Clark, 1874. Amer. Nat., vol. VIII, p. 363.

Mentions occurrence of *Achlya prolifera* (?) on live fish in a house aquarium, giving method of treatment, etc.

Cooke, 1880. Grevillea, vol. IX, p. 9. (Copied in Jour. Roy. Micr. Soc. 1880, p. 997.)

States that Rutherford found bacteria present in muscles of diseased salmon, which he thought might cause the disease. Cooke thinks it due to *S. ferax*.

Cooper. Micr. Jour., vol. I, p. 149.

Notes a fungous growth that killed goldfish.

De Bary, 1888. *Botanische Zeitung*, p. 617.

Mentions *S. mixta* as found on sick fish.

Farlow and Seymour, 1891. Host Index U. S. Fungi, p. 179.

Mentions *S. ferax* as reported in United States on several kinds of fish.

Fischer, 1892. *Raben. Krypt. Flora (Pilze)*, Lief. L., pp. 337, 340.

Mentions occurrence of *S. monoica* and *S. thureti* on dead fish, and *S. mixta* on sick fish.

Gerard, 1879. Proc. Poughkeepsie Soc. Nat. Sci. 1878, p. 25.

Gives an account of an epidemic among fish of Passaic River, N. J., in which species affected in order of mortality were as follows: Sucker, mullet, chub, roach, sunfish, yellow perch, catfish, and a few pickerel.

Goodsir, 1846. Trans. Bot. Soc. Edinburgh, vol. I. (Article noticed in Bot. Zeit. 1846, p. 479.)

Describes a plant developing on gills and fins of goldfish.

Harkness and Moore, 1880. Pacific Coast Fungi, p. 32.

S. ferax mentioned as common on dead flies and living salmon.

Hine, 1878. Amer. Quart. Micr. Jour., vol. I, pp. 20, 145.

In a general article on *Saprolegniaceæ* mentions forms parasitic on fish, etc.

Hoffman, 1867. *Botanische Zeitung*, p. 345.

In an article on the relation of a *Saprolegnia* and a *Mucor*, mentions the occurrence of the former on fish.

Huxley, 1882. Quart. Jour. Micr. Soc., vol. XXII, n. s., p. 311. (Abstract of article in Am. Month. Micr. Jour., III, p. 137.)

Treats of *Saprolegnia* in its relation to epidemic disease among salmon.

Knight, 1885. Bull. Torrey Bot. Club, vol. xii, p. 56.
Notes that a goldfish succumbed to attack of *S. ferax.*

Lambotte, 1880. *Flore Mycologique Belge*, p. 112.
In a description of *S. ferax*, says it occurs on dead fish, salamanders, etc.

Lindstedt, 1872. *Synop. der Saprolegniaceen*, pp. 39, 42, 46.
Mentions *Saprolegnia* as being found by old authors on dead and living fish, and gives *S. ferax* as occurring on dead fish, etc.

Lockwood, 1890. Jour. N. Y. Micr. Soc., vol. vi, p. 67.
Gives an extended popular and scientific account of *S. ferax* on sunfish, etc.

Murray, 1885. Journal of Botany, vol. xxiii, p. 303.
Gives notes on inoculation of fish with *S. ferax* and says disease was introduced into aquarium through earthworm.

Peck, 1886. Thirty-ninth Rep. N. Y. State Mus. Nat. Hist., p. 49.
Notes *S. ferax* as found on aquarium fish and those in artificial ponds in New York.

Robson, 1880. Science Gossip; also Amer. Month. Micr. Jour., vol. i, p. 103.
An article on salmon disease said to be due to *S. ferax.*

Ryder, 1881. Bull. U. S. Fish Com., vol. i, p. 181.
Mentions a saprolegnious growth quite destructive to fish eggs.

——, 1882. Bull. U. S. Fish Com., vol. ii, pp. 189, 190.
Gives account of action of *S. ferax* and of attempted preventive experiments

Schenck, 1890. *Handbuch der Botanik*, vol. iv, p. 567.
Gives *S. thureti* of De Bary as occurring on dead and living fish, their eggs, etc.

Schnetzler, 1888. Mag. Nat. Hist., vol i, p. 162.
Mentions a tadpole's becoming infected with *S. ferax* by spread of the fungus from a fly.

Schroeter, 1889. Krypt. Flora von Schlesien, pp. 256, 754.
Gives scientific descriptions of *S. monoica* and *S. ferax*, and says they occur on dead insects, organic matter, living fish, etc.

Smith, 1878. Gardener's Chronicle, vol. ix, p. 560; also Grevillea, vol. vi, p. 152.
Gives account of a disease of salmon in rivers of northern England.

Stirling, 1877–78. Proc. Roy. Soc. Edinburgh, vol. ix, p. 726. (Reprinted in Rep. U. S. Fish Comm. 1878, p. 525.)
Gives account of a destructive epidemic among salmon and other fishes in rivers of Scotland, due to *S. ferax.*

——, 1878–79. Proc. Roy. Soc. Edinburgh, vol. x, p. 232. (Reprinted in Rep. U. S. Fish Comm. 1878, p. 531 and p. 370.)
Gives additional observations on the fungous disease affecting salmon and other fish.

Swan, 1888–89. Rep. and Proc. Belfast Nat. Hist. Soc., pp. 54–85.
Gives life-history of *S. ferax* and its relation to salmon disease.

Trelease, 1884. Parasitic Fungi of Wisconsin, p. 4, No. 3.
Gives *S. ferax* (Gruithus) form *Thuretii* de Bary, as obtained on fly cultures in water at Madison.

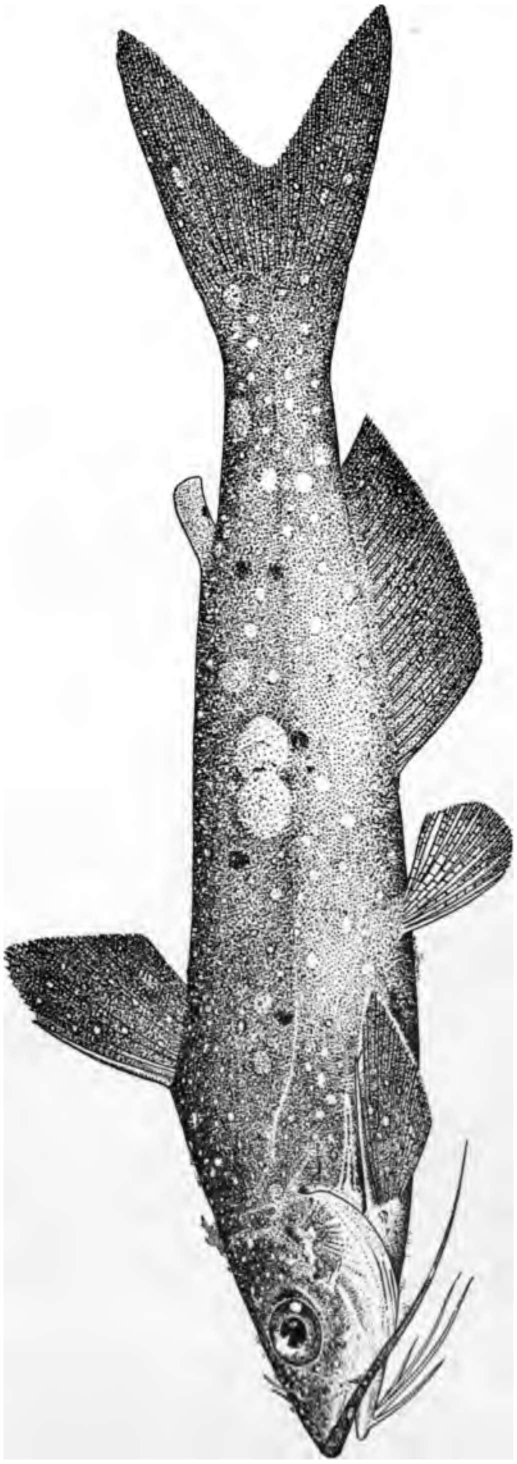
Valéry-Mayet, 1885. Bull. U. S. Fish Comm., vol. v, p. 272.
Extract from letter giving account of trouble with supposed *Saprolegnia* in hatching salmon eggs.

Walpole and Huxley, 1881. Twenty-first Ann. Rep. Inspectors Fisheries England and Wales. (Reprinted in Bull. U. S. Fish Comm., i, p. 429.)
Authors give a very comprehensive account of the salmon disease of rivers of England and Wales. Mature state of fungus not being found, absolute determination of species was impossible.

To the above may be added the following references to early writers who note the appearance of this or similar fungi on various aquatic animals, as salamanders, frogs, etc.: *Carus*, Nova Acta, 1823, vol. ii, p. 493; *Hannorer*, Müller's Archives, 1839, p. 338, and 1842, p. 73; *Stilling*, Müller's Archives, 1841, p. 279; *Valentin*, Repertorium, vol. v, p. 44.

Bull. U. S. F. C. 1893. On a Parasitic Protozoan. (To face page 173.)

PLATE 11.



CATFISH (*Ameiurus albidus*) infested with *Ichthyophthirius multifiliis.*

REPORT ON A PARASITIC PROTOZOAN OBSERVED ON FISH IN THE AQUARIUM.

BY CHARLES WARDELL STILES, PH. D.,
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INTRODUCTION.

During the early part of the Columbian Exposition season a lot of young catfish (***Ameiurus albidus***) were brought to the aquarium from the Potomac River and some time after were discovered to be seriously infested with a protozoan parasite. The general pressure of aquarium operations prevented any special study of the subject until a spread of the parasitic disease to other species adjacent, notably to young trout, compelled attention to it. Some preliminary studies made by Prof. S. A. Forbes, director of the aquarium, resulted in a determination of the parasite as a species of the genus *Ichthyophthirius* of Fouchet, and some practical experiments with solutions of common salt, copperas, carbolic acid, and other materials, showed that the parasite was easily destroyed in a free state by several of these substances. It seemed necessary, however, that solutions should be found capable of destroying the parasite while imbedded in the mucous layer of the skin without injury to the fish infested—an undertaking which required a large amount of continuous work, systematically planned with reference to both scientific and practical ends. Prof. Forbes consequently applied to Secretary Morton, of the U. S. Department of Agriculture, for the temporary transfer of the author of this report from the Agricultural Department to the U. S. Fish Commission, with a view to having such methodical experimental work carried forward until definite results were reached.

Arriving at the aquarium in July, I found that in some tanks scarcely a catfish or a trout was free from the parasites. The latter were perfectly visible to the naked eye, and were scattered over the entire external surface of the fish. They were numerous on the gills and in the mouth, and in the case of the catfish they were also found in the stomach, the latter specimens probably having been swallowed. The protozoa were not entirely superficial, but were imbedded in the epithelial layer of the skin, lying in small round cavities large enough to contain but one or two individuals, or in elongated galleries or pustules (especially in the case of the catfish) containing numerous specimens of the ciliate. In most cases the fish were covered with a thick slime, which extended also into the mouth and covered the gills more or less completely.

The temperature of the water was high, running some days up to 74° F. (23·3° C.), and this factor should be taken into consideration in connection with the high mortality of the infested fish.

Fish infested with this parasite usually preferred the upper half of the tank. They gasped very rapidly and seemed unable to eat. When they took a morsel of food into their mouths, it was retained but a moment and then expelled. Gradually they would seek the surface of the water, become weakened and sluggish in their movements, and finally die.

The exact pathogenic action of the parasite on the fish I am unable at the present moment to explain, for although I examined a number of fish after death—many of which were considerably decayed before I could study them—I found no one gross lesion or set of lesions common to them all, other than the general injury to the epidermis and the enormous amount of slime present on the body and *over the gills*. I am convinced that the parasite is not a harmless object and that the mortality of the fish was not due solely to the high temperature of the water, for had this been the case fish in uninfested tanks would have been affected as well as those in the infested aquaria. Furthermore, even if one were inclined to claim that the temperature was the chief factor in the disease, he would be confronted by a fact which would be difficult to explain on that theory, *i. e.*, that the young catfish seemed to succumb more easily than the trout, although able to live in much warmer water. On the other hand, as the catfish were more seriously infested than the trout, the higher mortality of the former is more easily understood by assuming a pathogenic property of the protozoa in question.

Accordingly, while the specific pathogenic action still remains undetermined, I think there can be no reasonable doubt that this parasite contributed largely to the cause of the losses sustained by the aquarium.

The special problem before me was to find an inexpensive solution which would kill the parasites, but in which the fish could live. This in itself was not a difficult matter, for several solutions were soon made which were absolutely fatal to the protozoa when liberated from the fish, and in which the fish were able to live for several hours or even for several days. Upon applying these solutions to practical use, however, it was found that they had absolutely no effect upon the parasites as long as the latter remained in the epidermis or in the slime. Two methods of experimentation were then open: first, to find a solution which would cut or remove the layer external to the parasite and thus act as a carrier of the germicide; or, secondly, to study the life-history of the parasite in the hope of discovering some stage of its development during which it lived free in the water, then to kill this stage and thus prevent a reinfection of the fish.

While the details of these experiments* will be given below (cf. pp. 186–189), it may be stated here that the last-mentioned method was the only one which was found feasible. The three solutions which gave the best results were salt water, methylen blue, and eosine. To fully understand the action of these liquids, it will be necessary to give a description of the parasite and the details of its life-history.

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*These investigations are to be looked upon as field experiments, rather than as minute researches into the exact effect which the various solutions mentioned below have upon the fish, as they were carried on in an extemporized laboratory, and with a view to meeting the epizoötic at hand rather than placing on record details and minutiæ as to the exact number of seconds that various species of fish or the parasites could live in different percentages of strength of various disinfectants. Owing to the fact that I was obliged to make the experiments upon the grounds of the Exposition, it was necessary for me to borrow my instruments from the different Government exhibits at the fair, and it is with pleasure that I acknowledge here my indebtedness to Dr. Wiley and Mr. Fairchild for placing various instruments at my disposal; Dr. Kinyoun, of the U. S. Marine Hospital Service; Dr. Lagard, of the U. S. Army Hospital; John Wyeth & Bro., chemists, Philadelphia, and Merck & Co., New York, kindly furnished me with various chemicals, thus saving much trouble and expense.

THE PARASITE. Holophrya (Ichthyophthirius) multifiliis (Fouquet).

SYNONYMY.

1876. *Ichthyophthirius multifiliis* Fouquet.
1884. *Chromatophagus parasiticus* Kerbert.
1887. *Holophrya* (*I.*) *multifiliis* (Fouquet) Bütschli.
1892. *Ichthyophthirius cryptostomus* Zacharias.

HOSTS.

Schlammpeitzger (*Cobitis fossilis*) and others, Hilgendorf and Paulicki, 1869.
Von Behr trout (*Salmo fario* L.), Fouquet, 1876.
Tench (*Tinca vulgaris* var. *aurata*), Kerbert, 1884.
Bream (*Abramis brama* L.), Kerbert, 1884.
White bream (*Blicca bjorkna* Sieb.), Kerbert, 1884.
Carp (*Cyprinus carpio* L., with varieties; *C. rex cyprinorum* and *C. nudus*), Kerbert, 1884.
Goldfish (*Carassius vulgaris* Kröyer), Kerbert, 1884.
Golden ide (*Idus melanotus* var. *miniatus* Heck. & Kner), Kerbert, 1884.
Atlantic salmon (*Salmo salar* L.), Kerbert, 1884.
Von Behr trout (*Salmo fario* L.), Kerbert, 1884.
Brook trout (*Salvelinus fontinalis* Mitchill), Kerbert, 1884.
Brook trout (*Salvelinus fontinalis* Mitchill), Forbes & Stiles, 1893.
Von Behr trout (*Salmo fario* L.), F. & S. 1893.
Loch Leven trout (*Salmo levenensis* Walker), new host, 1893.
Rainbow trout (*Salmo irideus* Gibbons), new host, 1893.
Lake trout (*S. namaycush* Walb.), new host, 1893.
White bass (*Roccus chrysops* Raf.), new host, 1893.
Pike perch (*Stizostedion vitreum* Mitchill), new host, 1893.
Spotted catfish (*Ictalurus punctatus* Raf.) new host, 1893.
Young Mississippi catfish (*Ameiurus nigricans* Le Sueur), new host, 1893.
Channel catfish (*Ameiurus albidus* Le Sueur), new host, 1893.
Yellow catfish (*Ameiurus natalis* Le Sueur), new host, 1893.
Marbled catfish (*Ameiurus marmoratus* Holbrook), new host, 1893.
Whitefish (*Coregonus clupeiformis* Mitchill), new host, 1893.
Large-mouthed buffalo (*Ictiobus urus* Agassiz), new host, 1893.
Small-mouthed buffalo (*Ictiobus bubalus* Raf.), new host, 1893.
Sheepshead (*Archosargus probatocephalus* Walb.), new host, 1893.

GEOGRAPHICAL DISTRIBUTION.

Germany (Hamburg), Hilgendorf & Paulicki, 1869; (Plön), Zacharias, 1892.
France (Paris), Fouquet, 1876.
Holland (Amsterdam), Kerbert, 1884.
United States of North America (Chicago), fish came originally from the Potomac River, Forbes & Stiles, 1893.

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1876. Note sur une espèce d'infusoires parasites des poissons d'eau douce; Archiv. d. zool. expérimentale et générale, t. V, pp. 159–165, pl. IV, 1–11.
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HISTORICAL REVIEW.[*]

[†]Hilgendorf and Paulicki (1869) of Hamburg seem to have been the first to place on record observations concerning this form. They noticed that a number of different species of fresh-water fish in the aquarium of the zoological garden in Hamburg were troubled with a slimy excrescence, which was followed by a growth of fungus and finally by the death of the fish. In each excrescence was found one or more specimens of a large (0·5 mm.) protozoan. This parasite, which Hilgendorf and Paulicki thought might belong to Ehrenberg's genus *Pantotricha*, seemed to possess neither mouth nor characteristic form; it was covered with fine cilia arranged in longitudinal spiral lines and possessed a nucleus, contractile vacuole, vacuoles, and granules; it appeared to rotate always in the same direction. When the fish were placed in a special aquarium for study, it was noticed that the parasites left their host, fell to the bottom of the glass, encysted themselves, and multiplied by division. The small resulting oval bodies, Hilgendorf and Paulicki think, probably infest new fish. They believe that the function of the skin of the fish must be greatly disturbed by the presence of these parasites, and that the fungous growth was only secondarily concerned in the malady. Among the fish infested, the authors mention especially the "Schlammpeitzger" (*Cobitis fossilis* L.).

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[*] As very little literature was at my disposal while on duty at the World's Fair, the greater part of this historical review has been written since returning to Washington. Through the kindness of Prof. Forbes, however, I had access to Bütschli (1887), a review of Kerbert's work (1885), and to Fouquet's article (1876), while still in Chicago.

[†] Bei dem allgemeinen Interesse, welches den niederen Organismen für die Entstehung verschiedener Krankheitsprocesse in neuerer Zeit beigelegt wird, dürfte nachfolgende Beobachtung, welche in dem Aquarium des Hamburger zoologischen Gartens ausgeführt wurde, einer Mittheilung werth erscheinen. In den sämmtlichen Süsswasserbehältern wurde nämlich bereits seit langer Zeit an den verschiedensten Fischarten das Auftreten von schleimigen Excrescenzen beobachtet, die schliesslich zu Schimmelbildung und endlich zum Tode der befallenen Individuen führten. Die microscopische Untersuchung dieser Schimmelmassen zeigte nur die gewöhnlichen aufgequollenen Epithelzellen der Fischhaut. Aber schon bei der ersten Besichtigung trat eine Art von Infusionsthierchen, die sich durch verhältnissmässig enorme Grösse auszeichnete (bis 0.5 mm. im Durchmesser) in dem Gesichtsfelde auf, wurde indessen anfänglich für ein zufälliges Vorkommen angesehen. Die microscopische Besichtigung von besonders geeigneten Stellen des Fisches, z. B. den Bartfäden und Flossen, zeigte aber bald, dass jede einzelne Excrescenz im Innern einen scharf conturirten weissen Punct besass, der eine unverkennbare Aehnlichkeit mit dem macroscopischen Aussehen jener Thierchen verrieth, eine Vermuthung die sich bei Anwendung des Microscops völlig bestätigte.

Die betreffende Form, welche wohl zu der Ehrenberg'schen Gattung Pantotrichum gehören könnte, zeigt weder Mund, noch durch Grösse ausgezeichnet Wimperhaare oder Borsten, noch eine characteristische Körpergestalt; sie ist überall mit feinen gleichmässig entwickelten, in schwach spiraligen, gedrängten Längslinien stehenden Wimpern besetzt, und lässt nur noch einen (bei grossen Exemplaren hufeisenförmigen) Kern, die contractile Blase, Vacuolen und Körnchen erkennen. Ein Bartfaden von einem Schlammpeitzger zeigt die Einbettung des Thieres unter dem (hier gelblichen) Epithel und über der Schicht der Pigmentzellen aufs deutlichste. Die Epithellage bildet, ohne sonstige Veränderungen zu bieten, einen ansehnlichen Hügel über dem Parasiten, welcher sich in einer fortwährenden, anscheinend stets nach derselben Seite gerichteter Rotation befindet. Wenn, wie es öfter beobachtet wurde, eine Anhäufung von den Schmarotzern an einer bestimmten Stelle stattfindet, so verbinden sich die epithelialen Decken der einzelnen Individuen zu zusammenhängenden, ziemlich ausgedehnten Massen, welche den ganzen Körper des Fisches, Augen, Nasenröhrchen, Flossen, etc., übersäen.

In ein besonderes Glassgefäss untergebracht, verloren die Fische bald einen Theil der Infusorien, welche sich auf dem Boden des Glases ansammelten, und an diesen abgesonderten Thieren konnte nun

Thus, as we shall see, the first observers, although they did not go into minute details in regard to the microscopic structure of the parasite, made very exact observations on its life-history, and all the work on this form which has been done since then confirms most of their observations, corrects some slight errors, and supplements their description by furnishing details which escaped their notice.

Fouquet (1876) found numerous nearly spherical parasites, 0·3 mm to 0·8 mm in diameter, on small trout in Prof. Balbiani's laboratory (Collége de France, Paris), which he identified as the form found by Hilgendorf and Paulicki. They rotated, according to his observations, from left to right as well as from right to left in a cyst formed at the expense of the epithelium; the cilia were arranged regularly in rows as already noticed by Hilgendorf and Paulicki. In the cortical layer of the ciliate were found trichocysts and numerous contractile vacuoles, 0·03 mm in diameter. The endoplasm contained granules which carmine would not color and which were insoluble in caustic potash and only slightly soluble in ether and alcohol.

The larger specimens contained irregular patches of blackish pigment. The mouth was on the anterior extremity, non-contractile, 0·04 mm in diameter and surrounded by cilia which are slightly longer than those of the body; an œsophagus was present. Fouquet does not believe that this orifice can be used as a mouth, but rather that it serves as a sucker, while the parasite absorbs its nourishment by endosmosis. The nucleus is described as horseshoe-shaped, 0·30 mm long by 0·09 mm broad; the nucleolus could not be discovered in the adult, but was found in the young. When the parasite has reached a certain stage, it leaves the fish, falls to the bottom of the aquarium, forms a cyst around itself and divides in the series 2, 4, 8, 16, etc., until about 1,000 small cells are formed. The division is completed in about 40 to 50 hours, the time varying according to the temperature. On the third or fourth day the young, which measure 0·046 mm by 0·028 mm, escape from the cyst and seek new hosts. The trichocysts are more visible in the young than in the adult. The nucleus is 0·015 mm in diameter and in part incases the nucleolus, but each has its own membrane. The nucleolus measures 3·1 μ in diameter. Fouquet's attempt to infect fish with the young parasites gave negative results. The epizoötic began each year towards the end of May, and lasted two or three months. While Hilgendorf and Paulicki considered this parasite related to *Pantotricha* Ehrbrg., Fouquet considers it a representative of a new genus of *Heterotricha*, for which he proposes the name *Ichthyophthirius* (*I. multifiliis*).

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eine weitgehende Theilung nach vorheriger Encystirung beobachtet werden, während die unmittelbar vom Fische herabgenommenen Individuen nie die Andeutung eines Theilungsprocesses erkennen liessen. Theilthierchen wurden in verschiedenen Beobachtungen 2, 4, 8, 16 bis zu etwa 100 und darüber gezählt. Wurde die gemeinschaftliche Hülle durch Druck zum Bersten gebracht, so drängten sich die kleinen Nachkommen des Mutterthieres hervor und schwammen in schneller Bewegung als anfänglich ovale, rotirende Gebilde lebhaft umher.

Wahrscheinlich werden diese kleinen Theilsprösslinge wiederum einen Fisch aufsuchen, um an ihm durch reichliche Nahrung Wachstum und abermalige Theilungsfähigkeit zu erwerben, und um dann denselben, soeben dargestellten Kreislauf der Entwicklung zu wiederholen.

Die Fische selbst müssen natürlich, zumal durch massenhaftes Auftreten dieser Schmarotzerform bedeutend leiden, in dem sich die Oberhaut in Fetzen ablöst und die Function der Haut wesentliche Beeinträchtigung erfährt. Die Pilzbildung scheint erst auf dem abgestossenen Epithel als secundärer Process vor sich zu gehen, und darf somit wohl nicht als ein wesentliches Moment der Krankheit angesehen werden.

W. Saville Kent (1880–82, vol. I, p. 109) refers to *Ichthyophthirius multifiliis*, and creates (vol. II, p. 530) for it a new family, *Ichthyophthiriidæ* S. K., with the diagnosis:—

> Animalcules adherent, more or less ovate, ciliate throughout, oral cilia of larger size than those of the general cuticular surface, oral region adhesive, acetabuliform.

Saville Kent (vol. II, p. 531) seems to doubt the absence of a mouth because of the presence of black substance in the body and also upon other grounds. (Cited from Kerbert).

Kerbert (1884)* noticed a skin-disease on several of the fresh-water fish (see list of hosts, p. 175) of the Amsterdam Aquarium, caused by an infusorian parasite, which he thought was probably identical with the form described by Fouquet, but for which, on account of certain apparent differences in structure, he created a new genus and new species, *Chromatophagus parasiticus*, which he places in Saville Kent's family *Trachelocercidæ*. This disease has been termed "spot disease" (Flecken-Krankheit), and should not, according to Kerbert, be confounded with the disease "Pocken-Krankheit or pox," observed by Wittmack in various cyprinoids, where, "on the surface of the skin, there appear bluish-gray spots of a slimy, fungus-like character, which spread more or less over the entire body, and extend to the eyes, fins, etc." Kerbert never discovered any infusoria in pox, although Wittmack thinks the cause of the disease may possibly be traced to them. Spot disease, according to Kerbert, also occurs on salt-water fishes, but the ciliated parasite he found upon *Mustelus vulgaris* Müll. & Henle, and *Acanthias vulgaris* Risso, in the pulp cavity of numerous placoid scales, is probably not the same as the form he found upon the fresh-water fish, although Kerbert simply states that the rapid decay of the fish prevented him "from making a thorough examination of this species of infusorians."

Kerbert then discusses the views of Hilgendorf and Paulicki, and Fouquet, at some length. He, agreeing with Saville Kent, looks upon the dark granules in the infusoria as the remains of cutaneous pigment of the fish, and hence as positive proof against the view that these parasites have no mouth. He mentions a paper by Livingston Stone,† in which a cutaneous parasite of *Salmo fario* is described and figured, which Kerbert thinks is probably a rotifer rather than an infusorian. According to Kerbert also, La Valette St. George refers to the articles of Hilgendorf and Paulicki (1869) and Stone, but makes no further statements. As Kerbert's paper appeared in full in the Fish Commission report, it will suffice here if the barest outline of his results is given. The parasites measured 0·615 mm by 0·408 mm ; no trichocysts could be distinguished; mouth was lateral in position; pharynx was well developed; anus absent but the fæces were seen to escape from various points of the body. Reproduction not by fission, but essentially the same as described by Fouquet, the division always taking place in the dark.

Bütschli (1887) considers that the parasites found by Hilgendorf and Paulicki, Fouquet, and Kerbert are identical. He does not consider that *Ichthyophthirius* should rank as a genus, but makes a subgenus of it in the genus *Holophrya* Ehrbg., 1831, (subfamily) ‡*Holophryina* Perty, 1852 (Fam.) emend., family § *Enchelina* (Ehrbg.)

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* As Kerbert's original is not at my disposal, I quote from Kerbert 1885 and 1886.

† Domesticated trout: How to breed and grow them. Third ed.; Charlestown, N. H., 1877, p. 277. (Appendix I.)

‡ *Holophryinæ*, according to the rules of the International Zool. Congress.

§ *Enchelyidæ*, according to the rules of the International Zool. Congress.

Stein, 1860. Bütschli believes that the trichocysts of Fouquet are rather to be explained as a plasma structure,* and he seems to think that Fouquet's statement regarding the absence of a micronucleus in the adult is erroneous.

The following is Bütschli's definition of this family:

I. FAMILIE. ENCHELINA (Ehrbg.) Stein, 1860.

Gestalt meist mehr oder weniger monaxon; kurz bis recht lang gestreckt, jedoch häufig mit Neigung zur Bilateralität, seltener zur Asymmetrie. Der Mund liegt stets terminal oder ist doch nur sehr wenig nach hinten verschoben. Er ist meist rundlich, seltner etwas spaltartig in die Länge gezogen; gewöhnlich geschlossen, öffnet er sich nur während der Nahrungsaufnahme. Schlund, wenn deutlich entwickelt, eine gerade nach hinten ziehende kürzere oder längere, stets unbewimperte Röhre, die meist von einem mehr oder weniger deutlichen Stäbchenapparat umgeben ist. After in der Regel terminal. Die meist grobe Nahrung wird wohl immer durch Schlingen, nie durch Einstrudelung aufgenommen. Conjugation terminal.

I. UNTERFAMILIE. HOLOPHRYINA Perty, 1852 (Fam.) emend.

Bewimperung fast stets gleichmässig und allseitig, nur um die Mundöffnung zuweilen ein bis mehrere Kränze ansehnlicherer Cilien. Selten ist das Wimperkleid auf die vordere Körperhälfte beschränkt. Tentakelartige Gebilde fehlen; ebenso eine panzerartige Umhüllung.

Holophrya. Ehrbg., 1831 und 1838; Dujardin (1841); Cohn (1853); Stein (1854, 1859, 1869); Cienk. (1855); Cl. u. L. (1858-61); Eberhard (1858); Quennerstedt (1865-69); Mereschkowsky (1877-78); Maupas (1883); Daday (1886); Stokes (1887, 1888).

Synon., *Leucophra*, p. p. O. F. M. (1786); *Enchelys*, p. p. Diesing. (1866).

Parasit. Infusor. Hilgendorf u. Paulicki = *Ichthyophthirius* Fouquet = *Chromatophagus* Kerbert.

Taf. 56, Fig. 5-8 und 10.

Mittelgross bis ansehnlich (0.4). Gestalt theils regulär ellipsoidisch mit nahezu gleichen Polen, theils gestreckter bis cylindrisch; das Hinterende dann auch etwas zugespitzt. Biegsam, doch selten erheblich contractil. Mund terminal, selten ein wenig nach hinten verschoben (Lieberk.); spalt oder grubenförmig; manchmal von sphincterartigem Lippensaum umgeben, welcher auch etwas warzenförmig vorspringen kann. Zuweilen von dichter gestellten, etwas längeren, nach vorn gerichteten Cilien umgeben. Ein Schlund scheint theils zu fehlen, theils ist er deutlich und dann kurz spaltartig oder röhrig. Stäbchenapparat fehlen oder schwach entwickelt. After terminal. Contractile Vacuole gewöhnlich einfach, terminal; seltener daneben noch einige kleinere in einer oder mehreren Längsreihen über den Körper vertheilt (Lieberkühn) oder endlich sehr zahlreiche kleine (sog. *Ichthyophthirius*). Cilien zart. Ma. N. kuglig bis eiförmig, hufeisenförmig lang bandformig und dann gewunden bis rosenkranzförmig; selten in zahlreiche kleine Bruchstücke zerfallen. Mi. N. unbekannt. Nahrung grob und fein. Encystirung in gallertiger oder zarter Hülle; Cysten kuglig; zuweilen in denselben energische Vermehrung zu sehr zahlreichen kleinen Sprösslingen (*Ichthyophthirius*). Sichere Arten ca. 5-6. Süsswasser und Meer. Auch parasitisch (*Ichthyophthirius*) im Epithel der gesammten Körperoberfläche von Süsswasserfischen (Cyprinoiden, Salmoniden, Esox.)

Die Gattung *Holophrya* in dem hier angenommenen Umfang liesse sich in einige Sectionen oder Untergattungen zerlegen, welche aber durch Uebergänge wohl zu innig zusammenhängen, um als besondere Genera betrachtet zu werden.

Section I. umfasst die Formen mit einfacher terminaler Vacuole und verschiedenartig gestaltetem, einfachem Ma. N. (Typus *Holoph. discolor*).

Section II. diejenigen, bei welchen der Mund nicht mehr ganz terminal, sondern etwas nach hinten gerückt ist (eine unedirte von Lieberkühn beobachtete Form).

Section III. diejenigen, bei welchen zahlreiche kleine Vacuolen über die gesammte Köperoberfläche vertheilt sind (alleiniger Typus der sog. *Ichthyophthirius multifiliis* Fouquet = *Chromatophagus* Kerbert) und

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* "Die helle äussere Zone des Körpers (Corticalplasma wahrscheinlich) zeigt eine sehr deutliche radiäre Streifung, welche Fouquet auf Trichocysten bezieht (ich möchte sie für eine Plasmastructur halten). Dass allein diese kleinen Sprösslinge einen Mikronucleus besitzen, wie Fouquet versichert, rührt jedenfalls nur von der Schwierigkeit her, welche die Beobachtung dieses Gebildes bei den Erwachsenen bereitet."

Section IV. die langcylindrische sog. *Holophrya oblonga* Maupas mit fein zertheiltem Nucleus, die wahrscheinlich identisch mit der sog. *H. marina* Daday's (Makronucleus rosenkranzförmig) ist und welcher auch wohl der *Prorodon marinus* (Clap. u. L. 301, sowie Quennerstedt 408b und Möbius 1888) nahe steht. Letztgenannte Formen besitzen jedoch auch wohl Beziehungen zu *Chaenia* Quennerst.

Weissmann (1891) makes a passing reference to Fouquet's species as "an example of the phyletic origin of germs among the lower flagellata and gregarines."

Zacharias (1892*a* and 1892*b*) found an *Ichthyophthirius* on *Leuciscus rutilus* and *Alburnus* sp. kept in a large aquarium in the biological station in Plön. The parasites formed pustules in the skin of their hosts, and were situated especially on the head and along the lateral lines; in some cases the fish were practically covered with them. The ciliates measured 0·65 to 0·80 mm long by 0·50 to 0·55 mm broad; the dorsal surface is described as convex, the ventral surface as flat, and the entire body is covered with short (5μ) cilia; the protozoan possesses a large horse-shoe shaped nucleus, which is situated in the pointed anterior half of the body. By direct light the animal appears white; by transmitted light, grayish yellow. The anterior end is somewhat lighter in color than the middle and posterior portion, due to the uneven distribution of granules and crystals in the endoplasm. The endoplasm has a vacuolated structure and contains in the plasma between the vacuoles numerous round and angular refringent bodies. Besides these are found collections of dark granules (= pigment of other authors) probably to be looked upon as metabolic products. The thickest portion of the nucleus is at the bend and measures 0·05 mm. Like Fouquet, Zacharias believes that although the nucleolus is present in the young it is absent in the adult.

Zacharias states that no mouth is present, but on the ventral surface he found a depression 0·035 mm deep, 0·015 mm in diameter, which he interprets as a sucker by means of which the young fasten themselves to their host. He found no portions of food in the endoplasm, and experiments to feed powdered carmine were negative, from which Zacharias assumes that the parasites feed in some way upon the body fluids of their hosts. Contractile vacuoles were absent. As Fouquet's species presented a terminal anterior "mouth," and as this organ in Zacharias's species is situated ventrally in the anterior third, Zacharias looks upon it as a new species, for which he proposes the name *I. cryptostomus*.

Zacharias believes that the parasite which he observed is identical with the form found by Hilgendorf and Paulicki, basing this opinion on the statements of Hilgendorf and Paulicki that in their form the "mouth" was absent, while Zacharias doubts whether it could have been easily overlooked had it been terminal, as in the case of *I. multifiliis*. Furthermore, Hilgendorf and Paulicki state that the encysted parasite segmented into 100 to 150 young, this agreeing with the form examined by Zacharias, while Fouquet's species segmented into nearly 1,000.

Regarding the reproduction, Zacharias states that the ciliates which have left the fish lose their cilia and form a cyst around themselves, which he looks upon as the thrown-off cuticle, the content dividing until the young cells measure 0·075 mm in diameter. The macronucleus of the young measures 0·025 mm, the micronucleus 0·004 mm, and the cilia of the young are about twice as long as the cilia of the adult. As the young globular animals become oval or ovoid the globular nucleus elongates and becomes crescentic. While former authors had not found any stages of reproduction while the parasites were still on the fish, Zacharias states that he frequently found "encysted" individuals on young *Leuciscus rutilus*, but does not say whether these were in process of segmentation.

According to this author the injury to the fish is due to the fact that the epithelium is injured by the ciliate, and thus places are exposed where fungi (especially *Saprolegnia ferax*) gain a hold. The latter then retard the function of the skin to such an extent that the fish soon succumb.

OBSERVATIONS AT THE WORLD'S FAIR.

The parasite (fig.1) found at the World's Fair is unquestionably an *Ichthyophthirius;* whether *Ichthyophthirius* should, however, be given generic rank, as Fouquet and Zacharias have concluded, or whether it should be considered as a subgenus of the genus *Holophrya*, as Bütschli contends, is perhaps still an open question. Personally I lean decidedly to the view of Fouquet and Zacharias, that *Ichthyophthirius* is entitled to generic rank, but prefer at present nevertheless to follow rather than oppose an authority like Bütschli, unless supported by stronger evidence against his view than I have at present. Accordingly, I have accepted *Ichthyophthirius* as subgenus. The question of the specific relations between the form I have studied and the animals studied by Fouquet and others will be discussed further on.

In many respects the observations made agree perfectly with observations of other authors, as given previously; some of my observations may, however, be interesting and worthy of record, as they tend to complete the descriptions reviewed above as well as to explain some differences of opinion expressed by various authors.

The size of the animals now under consideration agrees approximately with the figures given by Fouquet and others, *i. e.*, up to 0·7 mm or 0·8 mm in diameter. These figures are, however, *estimated*, as no means for exact measurement were at my disposal. The body is round to elongate oval in shape when at rest, but changes its form almost as much as an amœba. This change is naturally not due to pseudopodia, but to its twisting, turning, and contracting. Deep grooves may extend across its outer surface, or the body may be perfectly smooth superficially; it may be flat on one surface and convex on the other, or it may be nearly spherical; in fact, it may assume almost any form when in motion. When at rest the body becomes globular or oval, and this should perhaps be looked upon as the normal form, as it agrees with the form of the young. Even when not progressing in the water, but remaining apparently in one place, the animal is in constant motion, revolving not only to the right and left, but in every other direction, that is, dorso-ventrally, ventro-dorsally, diagonally, etc. This may perhaps explain the statements of different authors in regard to the position of the mouth, for, as we saw above, Hilgendorf and Paulicki state that the mouth is absent (in other words, they observed none); Fouquet found the mouth (sucker) terminal and anterior; Kerbert placed it on the left side, and Zacharias on the ventral surface in the anterior third.

According to my observations, when the animal has assumed an elongated form, one end being more pointed than the other, the mouth (fig. 1) is *frequently* situated terminally at the pointed extremity, while the nucleus is nearer the other extremity. If we observe the animal for some time, however, we notice that any given point of the surface of the animal may come to lie at the pointed portion; that is, any portion of the animal may become pointed, and hence appear as if it were the anterior extremity, and as fast as the pointed portion shifts the mouth will also apparently change its position, at one moment being apparently at the anterior end, at the *apparent* posterior end, on the right or left side, or on the dorsal (fig. 2) or ventral surface. In all cases, however, I find the mouth at the pole opposite to the nucleus. On account of this constant apparent shifting of the mouth in position, I am led to doubt the validity of its apparent position as a specific character, and hence to call into question Zacharias's species, *I. cryptostomus*, distinguished from *I. multifiliis*, as we saw above, by the *antero-ventral* instead of *antero-terminal* position of the mouth. If we now compare figs. 1 and 2 of Zacharias's species with the statements just made, we see that our statements agree in so far that the mouth and nucleus are opposite each other, for he figures the mouth (fig. 2) as ventral, the nucleus (fig. 1) apparently as dorsal of it, *i. e.*, he has drawn a dorsal view, according to his interpretation of the topography, and in this view the nucleus is anterior. I have seen this same relation dozens of times in the form observed at Chicago.

Kerbert's figures, 1 and 3, support the statements here made, that the mouth and nucleus are at opposite poles and that the mouth apparently shifts* in position.

Agreeing with Fouquet and others, I find the mouth round and noncontractile; surrounding the aperture is an area which is thickened slightly and devoid of cilia (others have found the cilia longer in this position than over the rest of the body), but the inner margin of the oral aperture, as well as the œsophagus, is provided with them. A short ciliated œsophagus is present. As stated previously, Fouquet and Zacharias believe that this oral aperture acts as a sucker rather than as a mouth. While not denying the possibility of its acting as a sucker, although I have seen no proof for the view, I see no reason for denying that food can enter the body through this opening. The oral and œsophageal cilia certainly would be of more use in forwarding food than in sucking fast to an object, yet at the same time I have not seen any food enter through this aperture, nor, as I intimated above, have I seen it act as a sucker. No anus was discovered, neither could I confirm Kerbert's statement that the fæces were expelled from various points on the surface; I was also unable to discover any trichocysts.

The entire body, with the exception of a narrow zone immediately surrounding the oral aperture, is covered with short cilia arranged regularly in rows.

The protoplasm of the body is indistinctly divided into an endoplasm and an ectoplasm. In the ectoplasm are found numerous globules, such as have been described by former authors, and numerous contractile vacuoles. The latter are arranged, apparently in no regular order, throughout the entire ectoplasm, but each vacuole seems to be a more or less permanent structure, *i. e.*, as soon as a vacuole has emptied itself to the exterior through a minute but perfectly visible canal it appears again at the same point. Following one vacuole under the microscope for some time I found that it contracted on an average every 7 seconds.

The endoplasm contains very numerous globules and a crescentic nucleus, both of which have been sufficiently described by former authors.

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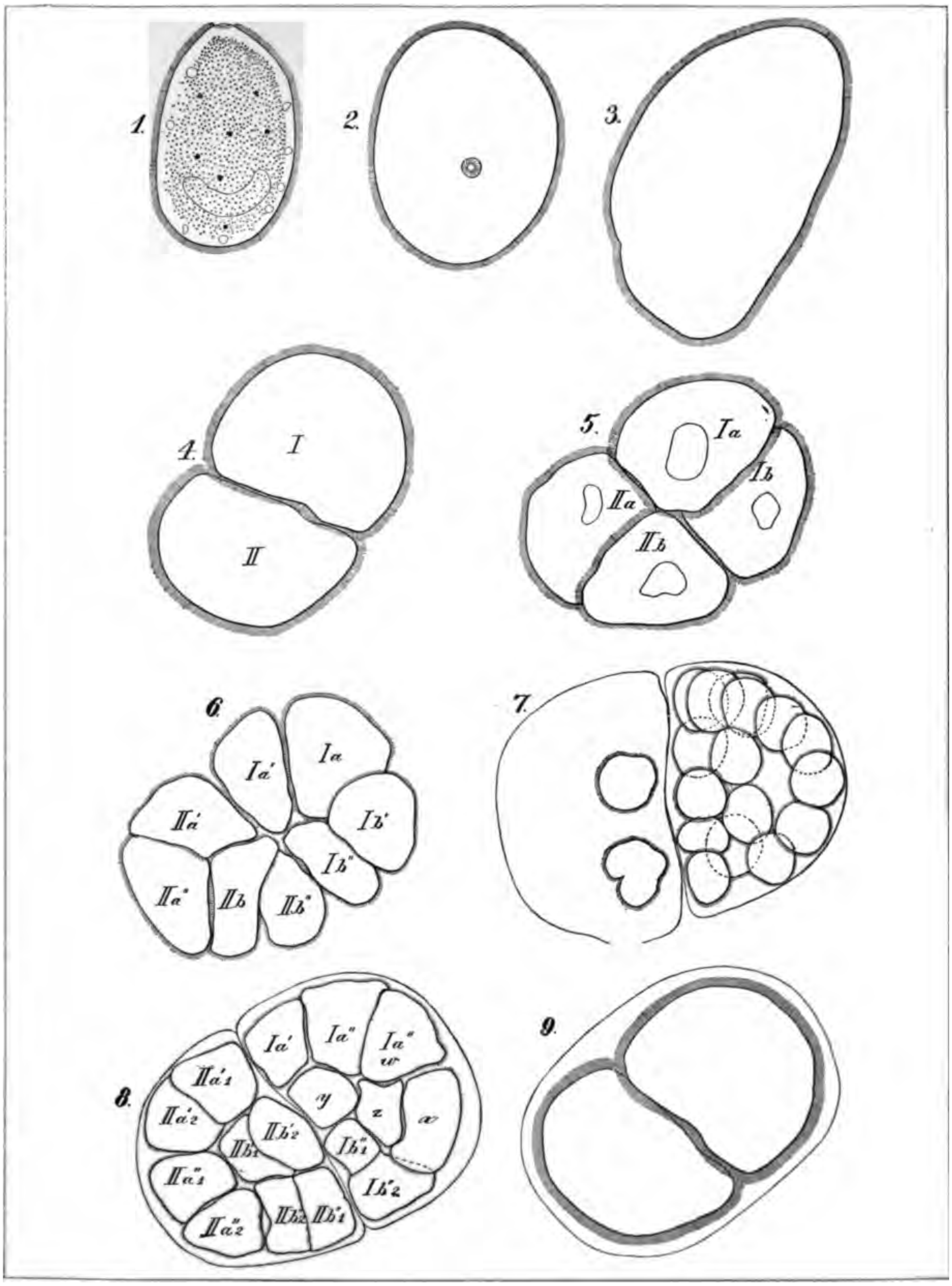
*This apparent change in the position of the mouth is, of course, nothing more nor less than a general change in orientation of the entire body.



1. *Ichthyophthirius multifiliis* showing ectoplasma, endoplasma, granules, pigment, contractile vacuoles, nucleus, mouth, and cilia.
2. The same; the animal has changed its orientation so that the mouth is turned towards the observer.

3-8. Semidiagrammatic figures of the division. The cyst appears in the 16-cell stage (beginning of the 16-cell stage).

3. One-cell stage, seen at 1 o'clock p. m.
4. Two-cell stage, at 1:45 p. m.
5. Four-cell stage, 3:15 p. m.
6. Eight-cell stage, 4 p. m.
7. Sixteen-cell stage, 5 p. m.; the membrane is present.
8. Thirty-four-cell stage, formed at 7:30; membrane broke at 8:20.
9. One of the ciliates encysted in its 2-cell stage.

Reproduction.—Former authors have described the multiplication of these parasites after leaving the host as taking place only in an encysted stage, but, as will be seen below, I have found several variations in this multiplication which may serve as connecting links between a simple division, as seen in other protozoa, and the reproduction as described by the authors mentioned above. In the case of one specimen, for instance, which I liberated from the fish and then placed in a hanging drop, the movements, which were at first very rapid and in all directions, gradually became slower and the animal revolved in but one plane. At the end of about an hour, without forming any cyst around itself, it divided and each half swam off independently of the other, resuming the rapid motion. This observation demonstrates beyond a doubt that *Ichthyophthirius* is capable of reproduction by division, without first becoming encysted, which is, I believe, a matter of considerable importance from a practical standpoint, for former authors have observed—and I have above confirmed their statements in this regard—that it is not unusual to find several specimens of the parasite in a single epithelial pustule or gallery, and this may occur even when infection is comparatively light. There are only two possible explanations for such an occurrence. Either a multiple infection has taken place at the same point, or a single infection has taken place and the parasite has grown and multiplied *in situ.* The probabilities appear to me to favor the latter explanation, especially in view of the above observation upon a specimen artificially liberated from the host.

Fig. 3 represents a specimen which had escaped from a trout and come to rest at the bottom of a glass jar at about 1 o'clock p. m. The animal was revolving very slowly in different directions, so that the mouth was turned toward the observer at one instant, in the opposite direction, or to the right or left the next instant.

At 1:45 it had divided (fig. 4) into 2 cells, I and II. Each cell revolved independently of the other, but they remained close together, although no surrounding cyst membrane could be discovered.

At 3:12 the cells had divided again (fig. 5), I giving rise to I*a* and I*b*, II giving rise to II*a* and II*b*. No cyst was visible; cilia were present and the 4 cells were in constant motion.

At 4 p. m. (fig. 6) I*a* had divided into I*a*′ and I*a*″; I*b* into I*b*′ and I*b*″; II*a* into II*a*′ and II*a*″; II*b* into II*b*′ and II*b*″. By no test, either by direct or oblique light—coloring methods could of course not be used—could I distinguish any cyst-membrane around this 8-cell stage. Every cell continued to revolve slowly in its own area.

At 5 p. m. the 16-cell stage (fig. 7) was reached. II*a*′ had given rise to $\mathrm{II}a'_1$ and $\mathrm{II}a'_2$; II*a*″ to $\mathrm{II}a''_1$ and $\mathrm{II}a''_2$; II*b*′ to $\mathrm{II}b'_1$ and $\mathrm{II}b'_2$; II*b*″ to $\mathrm{II}b''_1$ and $\mathrm{II}b''_2$; I*a*′ to $\mathrm{I}a'_1$ and $\mathrm{I}a'_2$; I*b*″ to $\mathrm{I}b''_1$ and $\mathrm{I}b''_2$.

All of these divisions were observed directly and continuously. There can, therefore, be no doubt as to the origin of the various cells. The origin of the cells *w*, *x*, *y*, and *z*, however, can be given with less certainty, although it is almost beyond question that *w* arose from I*a*″ and *x* from I*b*′ and it is probable that *y* arose from I*a*″, and *z* from I*b*′.

During the formation of this 16-cell stage a distinct surrounding membrane gradually came into view, not, however, a common membrane inclosing all 16 cells in one cavity, but a separate cyst for each group of 8 cells which had resulted from the two cells I and II (of fig. 7) respectively, while between the two groups the membranes appeared to unite in a common wall. Whether they really united, however, or whether the distance between them was so slight as not to be recognized (cf. fig. 8), I am of course not able to say, as any attempts to demonstrate the true condition would have destroyed the specimen for further observation.

At 5:30 the cells had changed position slightly, but no further division had taken place.

By 7:30 the 32-cell stage was reached, but it was impossible to follow the origin of the various cells, as they changed position so rapidly.

At 8:30 the membrane surrounding the small cells resulting from cell II (fig. 9) broke, and all the young ciliates except three escaped.

By 10 o'clock the cells of cyst I had undergone another division. I was able to count 27 with certainty, and in all probability this represented a 32-cell stage of this cyst (64-cell stage of the original animal), as several cases of doubtful division were not included in the number 27. One of the cells remaining in cyst II had divided, but the other two remained intact.

At 11 p. m. another division had taken place in cyst I; the resulting cells were about the size of the cells of the 64-cell stage, and this theoretically evidently represented a 64-cell stage of cyst I (128-cell stage of the original animal), although the young animals now revolved and changed place so rapidly that it was utterly impossible to count them. No change was noticed in cyst II, or in the cells which had escaped from cyst II and were swimming around in the preparation.

At 12 m. no change had taken place, and the preparation remained the same until 1:30 a. m., when it was placed aside for the night.

At 11 a. m. nothing could be seen of cyst II; cyst I had broken, and its contents, for the most part, had escaped, while the cells remaining in the cyst were dead.

A number of other cases of division were observed, which were essentially the same as the one just described. In many cases, however, it was impossible to follow the origin of the various cells beyond the 8-cell stage, and considerable variation was noticed in the time of the appearance of the surrounding membrane. The following are some of the more important observations:

Many of the ciliates become encysted while still on their hosts, and there undergo a division. I have found cysts of the 1, 2, and 4 cell stage on the host, but never any beyond this stage. [*The hosts had been dead for several hours.*] Many of the parasites encyst themselves shortly after leaving their hosts *before* any division takes place.

The first division may take place before any encystment, one cell swimming off and apparently undergoing no further division (for the time being, at any rate), while the other cell remains quietly in its place, encysts itself and divides into numerous small ciliates; or the first division may take place before any membrane appears, the two cells may swim around independently of each other; each may then become encysted and proceed to divide.

So far as my observations go, the surrounding membrane may appear in or at the end of the 1, 2, 4, or 8 cell stage. That is to say, I have observed these stages when, so far as I could discover, there was no membrane present, but when the membrane would gradually appear in the next succeeding (2, 4, 8, 16 cell) stage. I repeat, for emphasis, that I did not attempt to prove the presence of a membrane by resorting to any staining methods.

Zacharias has stated that the animal loses its cilia before encystment and has expressed his belief that the cyst-membrane is the thrown-off cuticle. From the above description it will be seen that my results do not agree with his. Admitting the possibility that the forms we have studied represent two different species, in which case we might perhaps expect to find some differences in the mode of reproduction, etc., I will repeat here that in the form Forbes and I have seen the cilia are not thrown off either before or during encystment; that the cyst-membrane in this case is not a discarded cuticle is shown conclusively by the fact that it appears at different stages of division. The origin of the cyst-membrane is not clear to me. The only explanation of its formation which occurs to me is that it is formed by an excretion of the cells which through the constant rotation of the latter is gradually moved centrifugally, condensing at a short distance from the organism.

I was unable to directly observe the division of any specimen beyond the 128-cell stage, as described above, but the division certainly goes beyond that stage, for not only have former authors described and figured it, but I have also found cysts containing more than 128 cells. Furthermore, the youngest stages found on the fish are smaller than the cells observed in the 128-cell stage.

In one case a cyst contained 4 cells at 3 p. m., 8 at 4:10, 16 at 4:25. At 11 a. m. on the following day it corresponded to the stage given by Fouquet as the final stage of division, and must have contained from 500 to 800, or possibly 1,000, minute cells, the latter corresponding to the description of the young given by Fouquet, except that I could not distinguish the trichocysts.

These young were also found swimming around on the bottom of a glass in which several trout had been confined, and were found in great numbers on the fish, so there can be no doubt that this is the stage which serves to spread the infection from fish to fish. It will be noticed that this stage was reached in less than 24 hours in the specimen referred to.

From the life-history as just given, in confirmation of the results obtained by former authors, it is evident that, although the parasites may, in all probability, multiply by division while on the fish, yet they eventually leave their host, swim around in the water for a time, become encysted, and run through successive divisions in the geometrical series 2, 4, 8, 16, etc., and reinfect fish as a minute body, invisible to the naked eye and about 30μ (estimated) long. As all experiments to kill the parasites while on the fish were unsatisfactory, it is evident that we still have a mode of prevention open to us in attacking the protozoan while it is free in the water. The problem of treatment now resolves itself into finding an inexpensive solution in which the fish can live until all the parasites have left the body, but the same solution must be fatal to the protozoa. The duration of life of the individual protozoan is a factor of considerable importance in this connection. It will be naturally expected that this will be subject to some variation and that no definite estimate can be made of it. Nor is it possible to directly observe how long one of the protozoa is able to live on the fish. In one of my experiments, however, a catfish was completely cleared of its parasites in about a week's time, while a trout was cleared in ten days' time, and these figures may form a basis for the estimation of the length of time it is necessary to subject the fish to treatment.

EXPERIMENTS.

A saturated salt solution kills the protozoa instantly, while the young trout, upon being transferred to it from fresh water, are killed in 10 to 40 seconds.

By placing salt at the bottom of a deep (about 4 feet) aquarium and allowing a constant supply of fresh water to run in with as little commotion as possible, we obtain a strong salt solution at the bottom, with a layer of fresh water at the top, while the water at different depths will be of different degrees of salinity. As the salt gradually dissolves, the fish seek the upper half of the aquarium as their abode, but frequently dive down into the briny water, sometimes even wallowing in the salt for an instant. The fish will live almost indefinitely in an aquarium arranged as just described, as has been demonstrated at the aquarium at the World's Fair, and elsewhere. As the parasites leave the fish they will, however, be killed upon reaching the salty water.

1. Saturated salt solution. 22° C.	Young trout (4 months old) overcome in 30 seconds; removed to fresh water, but did not recover. Parasites on fish for the most part alive. Those which fell from the trout during its rapid movements and struggles were killed instantly.
2. Saturated salt solution. 22° C.	Young trout (4 months old) affected instantly; killed in 10 seconds. Parasites on fish still alive.
3. Saturated salt solution, 50 cc.; lake water, 500 cc. 22° C.	Young trout affected immediately; overcome in 10 seconds, but revived in fresh water. Parasites on fish still alive.
4. Saturated salt solution, 50 cc.; lake water, 1,000 cc. 22° C.	Two young trout affected immediately; overcome in 10 seconds; revived in fresh water; placed again in solution No. 4; remained unaffected for 12 minutes, when they began to weaken; transferred to fresh water they revived again. Parasites on fish still alive; protozoa in water dead.
5. 9:45 a. m. Lake water, 500 cc.; saturated salt solution, 1 cc. 22.8° C.	9:45. Young trout placed in solution No. 5.
9:46 a. m. Saturated salt solution added, 1 cc.	
9:47 a. m. Saturated salt solution added, 1 cc.	
9:48 a. m. Saturated salt solution added, 2 cc.	Trout begins to weaken at 10:18, is gradually overcome, but revives in fresh water. Returned to same solution it is overcome in 40 seconds, but revives again in fresh water. Parasites on the fish are all alive, but those which have dropped into the water die instantly.
9:53 a. m. Saturated salt solution added, 5 cc.	
9:59 a. m. Saturated salt solution added, 5 cc.	
10:02 a. m. Saturated salt solution added, 5 cc.	
10:03 a. m. Saturated salt solution added, 5 cc.	
10:05 a. m. Saturated salt solution added, 5 cc.	
10:06 a. m. Saturated salt solution added, 5 cc.	
10:07 a. m. Saturated salt solution added, 15 cc.	
Total saturated salt solution, 50 cc.	
6. Lake water, 1,000 cc.; saturated salt solution, 150 cc. 24° C.	(*a*) One trout overcome in 4 minutes. (*b*) One trout overcome in 5 minutes. (*c*) One trout overcome in 12 minutes. Parasites on fish alive.
7. Lake water, 3,000 cc.; layer of ordinary salt on bottom of jar. 23.5° C.	(*a*) One trout overcome in 15 seconds. (*b*) Five trout remain alive 4 hours and are then taken out. During experiment the fish frequently showed signs of weakening and were then removed temporarily to fresh water and returned to the solution immediately upon recovery. Parasites on fish still alive; those which fell into the water were killed.

In the above experiments, except Nos. 1 and 2, fresh air was continually forced through the water.

8. Large aquaria, 4 feet deep; about 25 pounds of salt placed in each aquarium. Fresh lake water was constantly running in at the surface, but no attempt was made to force air through the water. Experiment performed by the attendants of the aquarium.	Tanks contained badly infested trout and catfish. Most of them stood the test well, and after two weeks the infection was greatly lessened. Some of the fish, however, still had parasites.
9. Methylen blue, 1 per cent aq. sol., 1 cc.; lake water, 200 cc.	(*a*) Trout alive at end of 2 minutes. Parasite also alive. (*b*) Trout died in 18 minutes.
10. Methylen blue, 1 per cent aq. sol., 10 cc.; lake water, 200 cc.	Trout alive; parasites unaffected at end of 5 minutes.
11. Methylen blue, 1 per cent aq. sol., 20 cc.; lake water, 2,000 cc.	Trout unaffected at end of an hour. Parasites on fish still alive; those which escaped from the fish die in the solution.
12. Methylen blue, 1 per cent aq. sol., 15 cc.; lake water, 500 cc.	Parasites, upon being freed from the fish and placed in this solution, died in 12 minutes. Trout were unaffected at the end of an hour.

For experiments Nos. 9 to 12 no air-pressure was available; temperature varied from 22° C. to 24° C.

13. Lake water, 10 L.; methylen blue, 1 per cent aq. sol., 30 cc.; constant aëration. 22° to 24° C.	Friday, 5 p. m. Five small trout badly infested, three of the fish very weak. Saturday, 9 a. m. One trout dead. Sunday, 9 a. m. One trout dead. Monday, 9 a. m. One trout dead. Wednesday, 9 a. m. Two catfish added.

Many of the parasites had fallen from the fish, and considerable scum had left them. This scum, together with the parasites, was colored blue by the methylen blue, and the solution was much weakened; 30 cc. 1 per cent methylen blue was added.

	Friday, 9 a. m. One catfish dead; the trout had lost most of their parasites. Monday, 12 m. Trout entirely free from parasites; a few parasites left on the catfish.

From this experiment it is evident that methylen blue is a substance which may be used to kill the parasites. It is, however, fatal to the fish if used in too strong solution, or if the fish are very weak. Although this experiment does not justify the unqualified use of methylen blue, it is very suggestive as pointing out a line for future research and experiment.

14. Eosin, 1 per cent aq. sol., 5 cc.; lake water, 500 cc.	Both fish (trout) and parasites alive after 10 minutes.
15. Eosin, 1 per cent aq. sol., 15 cc.; lake water, 500 cc.	Trout unaffected after two hours; parasites on fish still alive; those which fell from the fish died.
16. Lake water, 10 L. Eosin 1 per cent aq. sol., 60 cc. 23° C., constant aëration.	Friday, 5 p. m., 2 trout. Monday, 9 a. m., 2 catfish. Wednesday, 9 a. m., all alive.
17. Eosin solutions used in experiments 14 to 16 kill the free protozoa in 15 to 60 minutes.	The parasites have lessened in number; accident to jar ends experiment.

As the fish live very well in these solutions, eosin can be looked upon as another possible remedy for parasitical diseases of fish.

At the same time that the above 17 experiments were made, numerous other experiments were also carried on. Although the details of some of the other experiments will be given below, as of possible use to anyone who takes up this subject in the future, I am inclined to look upon the experments thus far given as the most suggestive for future work. It was my intention to experiment with these three substances—salt, methylen blue, and eosin—on a much larger scale, but at this point a combination of circumstances prevented my carrying out the matter further.

In most of the experiments given below, it will be noticed that the solutions had little or no effect upon the parasites, or that the fish were affected in so short a time that it was impracticable to experiment further with the solutions named. Constant aëration was employed.

18. Peroxide of hydrogen (H_2O_2), 1 cc.; lake water, 400 cc.	Small trout overcome in 17 minutes; parasites were unaffected.
19. H_2O_2 2 cc. Sat. salt sol., 3 cc.; lake water, 1,000 cc. 34°C.	Small trout lived 1 hour and then gradually weakened; parasites were unaffected.
20. H_2O_2, 1 cc. Sat. salt sol., 1 cc.; lake water, 500 cc. 24.8° C., 4:11 p. m. 4:42 H_2O_2 added, 3 cc. 4:45 Sat. salt sol., added, 3 cc. 4:54 Sat. salt sol., 2 cc. 5:00 H_2O_2, 1 cc. 5:02 H_2O_2, 1 cc. 5:15 Sat. salt sol., 1 cc.	4:11. Small trout. 4:48. Small trout. 5:16. Both fish slightly overcome but revived in water. Parasites on fish alive. Considerable scum had fallen from the fish and those protozoa which fell from the trout were killed.
21. * Ker. emul., 100 cc.; lake water, 400 cc.	Small trout overcome in 3 minutes, recovered in water. Parasites unaffected.
22. Kerosene emulsion, 666 cc.; lake water, 1000 cc.	Small trout overcome in 22 min., revived in water. About half the parasites and considerable scum fell from fish, but the protozoa were unaffected.
23. Kerosene emulsion, 100 cc.; methylen blue, 4 cc.; lake water, 900 cc. 23° C.	Small trout overcome in 2 minutes, revived in water. Parasites unaffected.
24. Ker. emul., 50 cc.; lake water, 500 cc. 23° C. 11:39. Methylen blue, 1 cc.	10:36. Small trout. 11:51. Some of the scum had fallen from trout. 12:10. Trout slightly overcome; revive in water. 12:20. Trout replaced in the solution. 4:00. Still alive. Parasites on fish and in water were unaffected.
25. Kerosene emulsion, 30 cc.; lake water, 500 cc.	Fish and parasites were unaffected after 3 hours; some of the scum was removed.
26. Kerosene emulsion, 500 cc.	(*a*) Trout overcome in 2 minutes. (*b*) Trout alive and well after 1 hour. Parasites unaffected. Some scum had fallen.

Kerosene cleans the fish to some extent, but has little or no effect upon the protozoa. The individual fish are affected very differently by the emulsion.

27. Creosote, 1 drop; lake water, 200 cc.	Trout overcome in 2 minutes but recovered in water. Parasites unaffected.
28. Creosote, 1:300 1 cc; lake water, 300 cc	Fish dies in 8 min., parasites alive at end of 3 hrs.
29. Vinegar 1 cc.; lake water, 200 cc. 12:35. Vinegar added, 1 cc.	12:30. Small trout. 2:00 p. m. Trout died, parasites alive.
30. Vinegar, 15 drops; lake water, 105 cc.	Trout affected immediately; free parasites die in 2 minutes.
31. Salycilic acid, ½ gram; lake water, 200 cc.	Trout dies in 4 minutes; parasites unaffected.
32. Permanganate of potassium, 1 minute crystal; lake water, 700 cc.	Trout lives 2 minutes; parasites unaffected.
33. Chlorinated soda sol., 2 cc; sat. salt sol., 5 cc.; lake water, 1,000 cc.	Small trout died in 3 minutes; parasites unaffected.
34. Same as No. 33.	Same result.
35. Tannic acid, 1 cc.; lake water, 500 cc.	Trout unaffected after 1 and 1½ hours; parasites unaffected.
36. Chl. soda sol., 2 cc.; salt sat. sol., 5 cc.; lake water, 500 cc.	Trout overcome in 3 minutes; parasites alive.
37. Same as No. 36.	Trout overcome in 2 minutes; parasites alive.
38. Seiler's tablets, 2; lake water, 2,000 cc. 3:45. Seiler's tablets, 2.	12:55. Small trout. 4:23. Fish partially overcome; parasites on fish alive, those in the solution dead.
39. Ferrous sulphate (copperas), small crystal; lake water, 2,000 cc.	11:43. Catfish. 3 p. m. Fish dead; parasites in solution dead, those on the fish still alive.

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* Two parts kerosene to 1 part milk.

40. Cupric sulph. sol. (blue vitriol), 15 drops; lake water, 2,000 cc. 24·3°.	Fish dies in 7 minutes; parasites unaffected.
41. Cupric sulphate, 1 cc.; lake water, 200 cc.	3:34. Small trout.
3:36. Cup. sul., 1 cc.	
3:38. Cup. sul., 1 cc.	3:42. Trout overcome; revived in water.
	3:56. Returned to solution.
	4:10. Dead; parasites unaffected.
42. 3:06. Potassium ferrocyanide, 1 per cent, 3 cc.; lake water, 700 cc.	Trout lived 3 hours. Parasites unaffected.
3:12. Pot. fer., 3 cc.	
3:15. Pot. fer., 9 cc.	
3:20. Pot. fer., 30 cc.	
43. 10:24. Pepsin, 1 teaspoonful; lake water, 1,000 cc.	Trout died in 3 minutes. Parasites still alive.
10:35. Sat. salt sol., 5 cc.	
10:50. Sat. salt sol., 5 cc.	10:55. New trout.
2:30. Salt sol., 5 cc.	Trout overcome at 3:00. Slime leaves fish to some extent. Parasites unaffected.

This experiment was tried with the hope of removing the slime from the fish by means of the pepsin, and thus reaching the parasites with the salt. The experiment was repeated a number of times, but the results were extremely variable.

44. Ichthyol, 7 drops; lake water, 500 cc. 23·5° C.	3:55. Catfish.
	4:32. Partially overcome and removed to fresh water; parasites alive.
45. Ichthyol, 3 drops; lake water, 3,000 cc. 35° C.	9:55. Weak catfish.
	10:30. Fish died.
	11:07. Second catfish.
	11:29. Parasites in water alive.
11:30. Ichthyol, 6 drops.	
11:45. Ichthyol, 6 drops.	
	12:00. Parasites in water alive.
12:01. Salt sol., 15 cc.	
	3:15. Parasites on fish alive; those in solution dead.
3:16. Ichthyol, 9 drops; salt sol., 15 cc.	
	4:45. Second fish partially overcome; died in fresh water; parasites on fish still alive.
46. Methyl violet, 2 cc.; kerosene emulsion, 20 cc.; lake water, 2 L., 23° C.	(*a*) 11:23. Trout.
	11:44. Overcome; revived in water.
	11:50. Returned to solution.
	2:20. Dead; parasites on fish and many of those in the solution are still alive.
	(*b*) 2:25. Trout.
	3:45. Fish dies; parasites unaffected.

It need hardly be stated that most of the above experiments were repeated two or three times. When the result was similar and unsatisfactory on two or three different fish, the experiment was discontinued.

SUMMARY.

The following may serve as a brief summary of the foregoing studies upon this parasitic disease:

(1) Two factors in particular, a protozoan parasite and the high temperature of the water, caused considerable loss among the fresh-water fish in the aquaria of the U. S. Fish Commission at the World's Fair in Jackson Park, Chicago. Although some of the fish of the aquarium were infested with fungi, the latter were not present upon many of the fish which I examined.

(2) This ciliated protozoan, belonging to the genus *Holophrya* (*Ichthyophthirius*), was imported by young catfish (*Ameiurus albidus*), and after a time spread to other fish.

(3) The species observed is evidently identical with Fouquet's *Ichthyophthirius multifiliis.*

(4) From a study of its morphology and reproduction, it agrees almost equally well with Zacharias's *I. cryptostomus*, and as the characters upon which his species is founded appear to me to be open to question, I am led to doubt, although not to positively deny, the validity of his species.

(5) *I. multifiliis*, as observed at the World's Fair, may multiply by simple division, or by division into numerous small ciliates after becoming encysted. The two modes of reproduction are, however, not sharply separated, as numerous gradations may be observed in this species. This reproduction is not confined to the night time, as Kerbert supposed.

(6) The encystment may take place either on the fish or after the parasite leaves the fish.

(7) The cyst-membrane may appear before division, or at any period up to and including the 16-cell stage.

(8) It is impracticable to try to kill the parasites while they are on the fish, for liquids endurable by the fish will not penetrate the slime in which the parasites lie.

(9) Experiments to digest this slime with pepsin or to wash it off with kerosene emulsion did not meet with sufficient success to warrant recommendation at present.

(10) The most practical method of destroying the parasite is to attack it during its free stage prior or subsequent to encystment, or during its encysted stage.

(11) The encysted stage lasts, according to my observations, about a day; according to Kerbert and others, from 2½ to 4 days.

(12) The young cells resulting from the division during encystment swim around in the water and then attack new hosts.

(13) Placing salt in the bottom of the aquarium and allowing a constant supply of fresh water seems at present to be the most feasible method of treatment.

(14) Very weak solutions of methylen blue and eosin give good results, but have the disadvantage of coloring the water. Fish can live in these solutions for a number of days, but the parasites which leave the fish to reproduce are killed in a few minutes. If these solutions are used, aëration must be resorted to.

19.—OPENING REMARKS OF THE CHAIRMAN OF THE FISH-CULTURAL SECTION OF THE FISHERIES CONGRESS.

BY EUGENE G. BLACKFORD.

There is very little that I can say on the subject of fish-culture that the gentlemen here are not already familiar with. I have not prepared any paper from lack of time. I can say from practical experience, and from my own observation, that we, the citizens of the United States, have good reason to be proud of the position that we hold to-day in the science of fish-culture. We have been honored by the different governments of the world in their sending embassadors and commissioners here to study our methods, that they might carry out the same system and plans for the increase of fish food in their own countries.

In the early history of fish-culture, and up to within twenty years, nearly all of the efforts have been bestowed on the artificial propagation of brook trout. Trout-hatching was the commencement of fish-culture, so to speak. After that had been started in this country by Dr. Garlick, followed by Mr. Ainsworth and Seth Green, attention was directed to the artificial propagation of other varieties of fish, and through the efforts of the American Fishery Society public interest has been stimulated and the fields broadened, so that what was in its first organization a "trout-culturist exchange" became the American Fish-Culturists' Association, and that expanded once more so as to take cognizance of everything in connection with the fisheries. That organization now stands under the title of the American Fisheries Society.

What I particularly desire to call your attention to are certain indisputable successes in the art of fish-culture—notably, the planting of young shad in the waters of the Sacramento, through the efforts of the U. S. Fish Commission, from which the waters of the entire Pacific coast are now abundantly stocked with this choice fish. A little over a year ago, while visiting the markets at San Francisco, I found shad there so abundant that they sold for 5 cents each. Many of these shad weighed as much as 12 pounds each. One of the marketmen told me that they had had several specimens during the season that weighed 15 pounds each. This, as you are aware, is a remarkable growth. I also saw striped bass weighing from 10 to 15 pounds each that had been caught in those waters. These fish a few years ago, and until the waters had been stocked by the U. S. Fish Commission, were not known in that region. Another item of interest in this connection is that the shad have gradually spread out, so that they are found on that coast as far north as the Columbia River.

These facts prove that fish-culture is an absolute and exact science, from which undoubted results can always be counted on, if it is carried out intelligently.

20.—STATISTICAL REVIEW OF FISH-CULTURE IN EUROPE AND NORTH AMERICA.

BY N. BORODINE,

Delegate of the Russian Association of Pisciculture and Fisheries.

During the last two years I have made a special study of fish-culture outside of my country, and visited many hatcheries of importance in Europe and North America. I have thus been enabled to collect some material, which is summarized in the following short review. The figures of North America were taken from the reports of the U. S. Fish Commission, State Fish Commissions, annual reports of the Ministry of Marine and Fisheries of the Dominion of Canada, and from the report of the superintendent of fisheries of Newfoundland. Those reports, regularly issued, are uniform, but do not include any information about private fish-hatcheries. For Europe the figures have been taken from scattered information in special literature, from official information furnished by the respective governments, and private information from the proprietors of fish-hatcheries which I visited personally.

I do not consider the following figures as absolutely exact; on the contrary I am sure that in one case, for want of regular reports, they are less than reality. Nevertheless I believe that a review of figures already known upon this matter may have some interest. Concluding these introductory remarks, I ought to say that I do not deal in this paper with pond-culture, the only object of comparison being the hatching of fish in the establishments specially constructed for that purpose.

The following table gives an idea of the number of fish hatched (in one season) in different countries of North America and Europe, with the date of information, number of fish-hatcheries, and expenses of the government for fish-culture.

Countries.	Date of information.	No. of fish hatcheries.	No. of fish hatched.	Annual appropriation for fish-culture.
North America:				
United States:				
State fish-hatcheries	1882-92	46	416,000,000	$174,040.00
U. S. Fish Commission	1891-92	20	491,200,000	150,000.00
Total United States	....	66	907,200,000	324,040.00
Dominion of Canada	1890-91	13	128,000,000	39,496.50
Newfoundland	1890-91	1	581,000,000	6,100.00
Total North America	....	80	1,616,200,000	369,636.50
Europe:				
Norway	1890	58	214,500,000	4,166.50
Germany	1891	90	25,500,000	21,815.00
Switzerland	1890	84	13,700,000	2,207.00
Great Britain	1891	16	8,600,000	....
Sweden	1891	34	5,400,000	....
France	1891	17	4,200,000	3,960.00
Austria-Hungary	1891	96	2,800,000	....
Italy	1891	5	1,100,000	....
Netherlands	1891	2	1,000,000	2,084.00
Russia	1891	14	1,000,000	2,800.00
Total of Europe	....	416	277,800,000	37,032.50
Grand total	1891	496	1,894,000,000	406,669.00

Most of the figures relate to 1891, so that we are able to consider the grand total for this year. On the other hand, all the principal countries being included in the table, we may estimate this total as representing the figures of fish-culture in the entire world. 496 fish-hatcheries are registered in the record, 416 of them in Europe and 80 in North America. The fish-hatcheries of North America, included in the table, belong without exception to the respective governments. Most of the European fish-hatcheries are private establishments, and only 82 out of 416 are controlled by their respective governments, viz, 14 in Switzerland, 1 in Germany, 5 in France, 2 in Italy, 58 in Norway, 1 in Great Britain, and 1 in Russia.

The totals of the fish hatched in North America (1,616,027,192) as compared with Europe (277,973,016) show that only about 14 per cent are produced in Europe; among European countries, only Norway, thanks to the active part taken by its government, can be considered as a serious competitor of the countries of the New World. The average production of one fish-hatchery is 668,000 in Europe and 13,400,000 in North America. Such a striking difference in favor of the New World is mainly due to the difference in the character of the hatcheries on both continents. As before mentioned, the European fish-hatcheries, being private establishments, do not pursue the task of restocking public streams, but only the streams belonging to the proprietors, and very often produce fry for sale to other proprietors of fish ponds, etc. Another circumstance to be mentioned in connection with the small size of European establishments is that no hatcheries—or very few—exist here for hatching *Clupeidæ*, *Percidæ*, and salt-water fish; the hatching of these kinds of fish, to be successful, ought to be conducted on a large scale. The last and most important question is the financial one. While the Government of the United States, of different States, and of the Dominion of Canada, grant very considerable amounts of money for fish-culture and take direct interest in this work, in Europe, with the exception of Norway, Germany, and Switzerland, the respective governments do not pay much attention to it.

The Government of the United States has a very important bureau, known as the U. S. Fish Commission, with annual appropriations of $298,000, viz: $150,000 for propagation of fish, $50,000 for distribution, $53,000 for maintaining vessels, $5,000 for compensation of Commissioner, and $20,000 for scientific investigations and statistical work. Besides this regular budget, the U. S. Fish Commission receives for extraordinary expenses, as, for instance, the construction of new hatcheries, new vessels, fish cars, etc., a considerable amount of money.

The governments of separate States also engage in this useful work, making large appropriations for building hatcheries and distributing fish. I must particularly mention the State of New York with a yearly appropriation of $34,000, the State of Michigan with an appropriation of $22,500, and the State of Pennsylvania with a grant of $15,000. The total amount of money granted for fish-cultural work by all the States is equal to $169,040 (1891).* The present appropriations are likely to be increased, because in very many reports I have examined the fish commissioners were asking for a larger amount of money.

The Government of the Dominion of Canada has been for a long time actively engaged in the propagation of fish. The expenditure for this work in 1891 was $374,202, which includes $39,496 for fish-breeding and $83,050 for fish-propagation.

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* General expenses of same States for fish-protection and carp-culture are not included in this total.

The Newfoundland Government works quite successfully with an appropriation of $17,300, that is, $6,100 for fish-culture and the remainder for fish-propagation and fishery administration.

In Europe, Germany expends the largest amount of money for fish-culture, say, $21,815, which includes $12,500 of subsidy to the Deutsche Fischerei Verein, the leading association of its kind in Europe, and $9,315 for the governmental fish-hatchery in Hüningen. Many private hatcheries exist in that country, thanks to the orders for hatched fry given by the above association, which has no hatchery of its own. The Hüningen fish-hatchery—perhaps the largest on the continent—has no value from the standpoint of the modern fish-culturist, and, with regard to the accommodation for the work, many private establishments[*] in Germany leave far behind this big, but inconvenient, old-fashioned hatchery, which, I think, has completed its historical rôle in fish-culture.

Norway is now one of the leading countries in regard to the work for all kinds of improvements in fisheries. Its government grants for this purpose an amount of $57,788 yearly, which includes $41,665 for fish-culture in particular.[†] One of the largest salt-water fish-hatcheries in the world, at Flodevigen, near Arendal (200,000,000 cod fry hatched in 1891), is controlled by a local fishery association and gets a subsidy of 9,000 kroners from the Government.

Next comes Switzerland, which operates, as compared with its area, on a very large scale. The Federal Government of that country has an appropriation of $2,207 for the fry planted by private persons in the public waters. Besides that, almost every canton has one, two, and sometimes several cantonal fish-hatcheries.

France—the cradle of pisciculture, the country which has contributed toward the development of this new industry more work than any other country—now ranks far behind many European countries. The French Government does not pay much attention to fish-culture in general, having an appropriation of 19,860 francs ($3,972) to maintain five not very large governmental fish-hatcheries and subsidize a private one (for shad-hatching at St. Pierre les Elbeuf, on the Seine River). Only quite recently, thanks to the statements made by the Société Centrale d'Aquiculture de la France, the attention of the French Government has been called to fish-culture, and I am informed that negotiations are being made to establish a special fish-culturist school at the Gremaz fish-hatchery, which belongs to M. Lugrin (the inventor of the method of artificially propagating live food for fish fry).

Italy has only recently begun fish-cultural work under the control of the Government, which has appropriated 32,000 liras ($6,500) for the construction of a large fish-hatchery at Brescia, now in operation, and has opened another small one at Rome.

The Netherlands Government appropriates only 5,000 gulden ($2,084) for the salmon fry planted in the Rhine River. No appropriation is made by the Austria-Hungary Government, fish-culture being carried on by proprietors and associations.

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[*] I can mention here the well-situated and nicely-fitted fish-hatcheries in Selzenhof, near Freiburg (8,000,000 trout eggs capacity), and in Seewiese, near Gemünden, Bavaria (4,000,000 capacity).

[†] The total of 208,040 kroners is thus distributed: For scientific investigation in fisheries, 5,200 kroners; subsidy to the fishery associations, 45,000 kroners (that includes 8,000 kroners for the hatchery at Flodevigen); maintenance of fishery schools in Bergen and Bodo, 11,500 kroners; fish-culture work, 7,250 kroners; and the remainder for fish-protection and administration.

The same remarks must be made in regard to Great Britain with the exception of Scotland, the fishery board of which erected last summer a salt-water fish-hatchery at Dunbar; no special appropriation was made for this purpose, the expenses having been covered by money assigned for scientific investigation (£1,800 yearly).

The Swedish Government contributes to some extent to the improvement of the fishery industries in its country, having a yearly appropriation of 47,000 kroners ($13,155), but that does not include any expense for fish-culture in particular.

And finally Russia has an appropriation of $2,800, which is, in comparison with its area, quite insignificant. That includes 3,000 rubles for maintaining one governmental fish-hatchery at Nicholsk, government of Novgorod, which was founded by the well-known Russian fish-culturist, Mr. Vladimir Wrasky, the inventor of the so-called Russian or dry method of impregnation, and 5,000 Finnish marks of subsidy to the Fishery Society of Finland.

When we compare the total amount of money spent for fish-cultural work by all European countries ($37,032.50) with the appropriations of North American countries ($369,636.50), we shall not be surprised by the enormous difference in the work done in this line in the Old and New World. Of course that is only an explanation of the fact, not an eulogy.

Europe has originated and developed the methods of fish-culture, but it becomes an industry only in America, and a very important one, from the standpoint of the Government. Only here is fish-culture carried on on a large industrial scale, and in connection with it here are invented and introduced in general practice methods suitable for large operations, quite different from those used in Europe.

There is no better testimony of the importance of fish-cultural work than the large appropriations made by the House of Representatives of the United States, and only in North America is this work duly appreciated by the Government as well as by most of the population.

21.—SOME NOTES ABOUT AMERICAN FISH-CULTURE.

BY OSCAR NORDQVIST,
Inspector of Fisheries of Finland.

A few days ago Hon. Marshall McDonald honored me with a request to write an article for the International Fisheries Congress in Chicago, containing a criticism on American fish-cultural methods. To thoroughly perform this task would require a far more comprehensive study of the subject than I was able to make during the four months I spent in America, and much more time than I have had at my disposal; still I feel it to be a debt of gratitude which I owe, both to the Fish Commissioner and the other fish breeders and scientists with whom I came into contact during my stay in America, to write a few of my impressions on fish-culture in that great country.

The enormous extent to which the work of fish-culture has attained in the United States may be at least partially attributed to the prevalent rights of fishing there. While in Europe either the State or private persons in most cases own fishing waters, nearly all such waters are public in the United States; that is to say, anybody may fish where he likes. As private citizens in that country can, therefore, have no direct interest in preserving or trying to increase the supply of fish, the General Government or the State must perform this duty. This has been done partly by the prohibition of fishing in all waters except the very largest, *i. e.*, the sea and the large inland lakes, and partly by fish-breeding on such a large scale that Europe can not show anything approaching it. As a consequence of this enormous fish-breeding, the Americans have invented a number of exceedingly simple, cheap, and easily managed apparatus for the purpose, and have thus materially simplified the work.

In the following article I only intend dealing with the breeding of fresh-water fish, which I have principally studied. Both in America and Europe the dry method is almost exclusively used for the fecundation of the roe, and therefore there is nothing specially characteristic in this in American fish-culture. A remarkable discovery, which has lately been made in America, is, however, worthy of notice, namely, Prof. Reighard's method of preventing pike-perch eggs from sticking together after fecundation, by keeping them for some hours in a dilution of starch. The Michigan Fish Commission used this method last summer on a large scale and with great success. In Europe the artificial fecundation of pike-perch roe has also been attempted, though only on a small scale. In these cases the roe has generally been made to attach itself either to well-washed grass-roots or to myriophyllum or other water plants. It has then been taken up and hatched in self-pickers, whilst sticking in this manner to water plants or other roots. This method is, however, scarcely suitable when hatching is done on a large scale and can not give such good results as when the eggs are hatched quite free from any other substances.

The manner of hatching heavy eggs in America in wooden troughs on wire trays, in which the eggs are laid in the troughs, either in single rows, or arranged one above the other, where they are washed by the water in the trough horizontally (Atkins), or where the water runs down from above (Clark), or is forced up from below (Williamson), seems to give as good results as can be desired, and the more complicated troughs with their many partitions do not appear to do the work any more satisfactorily. The simpler method, therefore, is much more in use. One apparatus, which I only saw at the U. S. Fish Commission's excellent exhibition, but never anywhere in use, is Livingston Stone's apparatus, which consists of a Williamson trough in which Mr. Stone, instead of a row of trays, had placed a basket made of wire cloth, and then laid the roe in many layers one above the other. I have specially mentioned this apparatus because many modifications of it have been introduced and are largely used in Europe under the name of the Californian apparatus.

The difference between the European modifications and the original American type chiefly consists in the replacement of the Williamson wooden trough, with its many divisions, by various small varnished tin boxes, each containing only one wire basket in which the roe is laid. These baskets are generally so small that they will only hold about 5,000 salmon or trout eggs. These so-called Californian apparatus are arranged one below another in the form of steps, so that water can run down from one into the other, and the results given are very good. Being of tin, and of small dimensions, generally about 40 cm. long by 25 cm. broad and 25 cm. high, they are also easy and convenient to handle. I also specially recommend to the American fish-breeder Max von dem Borne's funnel-shaped apparatus, which, although giving excellent results, only holds a few thousand salmon or trout eggs. It is especially suitable for hatching the rarer kinds of fish, of which there are only a small number to be had.

Whilst Europe can still well compete with America in the breeding of trout and salmon, and even has a station, Howietoun, in Scotland, which is larger than any in America, the latter country is far ahead of Europe in the culture of fish with semi-buoyant eggs, such as shad, whitefish, and pike perch. It is solely due to the self-pickers, first introduced by Fred. Mather and Charles Bell, and afterwards improved upon and perfected in various ways by Chase, Clark, Wilmot, and McDonald, that this great fish-culture has been made possible. It would be difficult really to say which of these four last constructions is the best for the purpose. I, for my part, should be inclined to give the preference, on account of its simplicity, to the Wilmot apparatus, which is made entirely of glass, but I think it would gain considerably in effectiveness if the bottom were made a little broader in shape, like McDonald's apparatus, and fitted, as his is, with three feet, by which a more regular circulation of water would be obtained. During late years a glass self-picker, constructed by a Swiss named Weiss, has also been successfully used in Switzerland and Germany. This has the shape of a bottomless bottle, turned upside down, the water rising up through the neck and running out over the edges of the bottom.

Concerning the packing and transfer of eggs there is not much to be said. The packing most used both in America and Europe is damp moss. On the other hand, in Canada, where the eggs are hatched on trays of perforated zinc, the same trays with a layer of moss on the eggs are often used for transferring them from the place of fecundation to the fish-breeding stations. In this way one avoids moving the eggs (which are very delicate) for some time after fecundation, besides saving oneself the trouble of doing so. Another way of packing, which is greatly praised by Mr. Wilmot, of Newcastle, Ontario, is that of covering the eggs with clean snow; and then there is the Russian method of packing in damp cotton, which, although I have never seen it done, is said to be very successful. As a rule the roe is not moved in Europe until the eye-spots are visible, but in America they seem to transfer quite newly spawned roe without any hesitation whatever, and in some cases the transit occupies several days. Thus, Mr. Clark tells me, it happens that lake-trout roe is a whole week on the way from the place of fecundation to Northville, where it is hatched without any part thereof worth mentioning becoming spoiled. I can not, however, but believe that roe which has been sent such a long way must give weaker fry than that which has not been moved, and in this belief I am supported by Mr. Page, in his address lately at the yearly meeting of the American Fisheries Society.

In the same way as the hatching of the roe is different in Europe and America, the fry are also treated differently in these countries. In America nearly all the hatcheries are exclusively intended for the production of fry or so-called yearlings, for planting in public waters. In Europe there are, however, besides stations for this purpose, a number of hatcheries where fish are bred in ponds or private waters for commercial purposes. With regard to the period before the fry has absorbed the yolk-sack, there is not much perhaps to be said, for this is a comparatively quiet time for the fish-breeder. The general experience is that it is better to keep trout and salmon fry in trays during this period, so that the water can also wash it from below and prevent its being stifled in the sediment at the bottom.

The next period is far more critical, when the fry begins to take in food. The fish-breeders of the old school have not, as is well known, troubled themselves about the fry during this period, but when the yolk-sack has begun to be absorbed they have let the fry out and allowed it to take care of itself. There is no doubt that in many cases this has also given good results, and this method will probably continue to be used for some time to come, but I, for my part, believe that as fish-culture becomes more and more developed the fry will be kept in the ponds until it has reached the age of six months or even a year. It is with the greatest interest that I have followed Mr. Atkins's experiments in feeding salmon fry until it has attained the age of one year, which required a great deal of care and attention. The results attained by this clever experimenter in breeding large quantities of salmon fry in a limited space have been very successful, and these experiments were the more interesting on account of Mr. Atkins having tried to replace liver, which until now has been almost universally used, by living food. This is, in my opinion, one of the important points for fish-breeders, as the use of artificial food, both for the animal and vegetable kingdoms, must be regarded as in a transition stage.

The feeding of fry, and also older fish, with natural food may be done in two different ways: the organisms intended for feeding the fish can either be cultivated in a separate place and then transferred to the basins or ponds where the fish are kept, or the fish themselves can be put into ponds which have been specially prepared, so as to produce a large quantity of organisms suitable for food. Each method has its advantages, but if there is plenty of room the latter way seems to me the most suitable. In America the custom is to build very small and shallow ponds, and Livingston Stone says, in his celebrated work on Domesticated Trout, "build your ponds small, that means business;" but I think you follow this advice far too closely in America.

The fish bred in especially large quantities in America, such as whitefish, shad, and pike perch, are nearly always let out as fry, in the stage when they begin to take in food. During late years, however, Commissioner McDonald has tried keeping shad in the ponds during the first year, and I think it would also be a great success if similar trials were made with whitefish and pike-perch fry. In some parts of Europe whitefish and pike perch are fed in large ponds until they reach a marketable size, and I can not help thinking that if the fry were kept at least the first year in ponds the results would be much better than those obtained by the present method in America.

The breeding of trout and shad has no doubt been attended with excellent results in many parts of that country, but as far as whitefish and pike perch are concerned much yet remains to be proved. It would certainly seem very useful to hatch the hundreds of million eggs (which otherwise would annually be lost) by catching the fish in its spawning-time and planting the fry thus saved; but statistics do not show that the supply of these particular kinds of fish is increased thereby. This may be attributed to the large scale in which the fishing trade is carried on, and it may be that, without hatching, these kinds of fish would have been exhausted, but all this is in any case only an hypothesis. It can not yet be shown conclusively how large a proportion of the whitefish and pike-perch fry that is planted attains the age of one year, and still less how many fish reach a marketable size.

We should doubtless be able to get nearer to the answers to these questions by planting the fry in large ponds and letting them remain there one or two years. But I should like to go further still. The culture of fish can not make any real progress by breeding only; there must be in addition sound legislation founded on a proper knowledge of the subject, and an effective enforcement of these laws. But how difficult it is to obtain a really thorough knowledge of the influence which the various factors exercise; what do we know as yet about the quantity of fish a certain water can produce, and how large a yearly demand it can sustain? And how little do we still know what tackle is at the same time the most advantageous for the fisherman and the least destructive for the fishery.

The only certain basis to go upon to judge of these and relative subjects is, I believe, to found experimental fishing stations, with the exclusive right to control the fishing in various lakes and streams for preference of different sizes and nature. At these stations fish would be bred, trials made as to the effect of different tackle and close times, artificial spawning beds laid down, water plants planted, and an examination made of the food produced by these waters and the best means of increasing the same, etc. In this way one would obtain a reliable account of the practical result of fish-breeding and a starting-point for fish legislation. A year ago I founded such a station in Finland, but lacking means and not having sufficient time now to devote myself to it as I should, it is not yet so organized as I would like it. It is to be for fish-culture what experimental farms are for agriculture.

There are yet many important problems to be solved in the breeding of fish, but the United States have won so many triumphs, and more especially since the formation of the U. S. Fish Commission, which has not only devoloped at an amazing rate, but has also done work of the most substantial value, that we must all hope for the continuance of their grand work of improving the breeding of fish, in which America is so much in advance of other civilized countries.

22.—FISH-CULTURE IN MICHIGAN.

BY HOYT POST,

Of the Michigan Fish Commission.

In this year of reminiscences it may not be amiss to briefly review the work done in fish-culture in Michigan. The record is found in ten biennial reports of the Michigan Fish Commission. This record, presumably like that of other States, shows some blunders, frequent mistakes, and many sad disappointments, but by persistence, energy, and pluck the blunders were overcome, the mistakes corrected, and the disappointments were borne with the Christian resignation which is characteristic of the craft. As an illustration of this spirit of resignation a quotation from the second report is in point. It says: "Now what is our lake and river farmer to do about it, when accident and insuperable force so confront him? What can he do more than did the honest Dutchman who, when he broke his leg, thanked the good Lord that it was not his neck. Few mortals, if any, can create circumstances, and the fish-culturist's work, like all other human work, must take its chances." The outcome has been a steady and continuous progress, resulting in a fair degree of success.

The board of fish commissioners of the State was established by an act of the legislature approved April 9, 1873. At this time seventeen other States had embarked upon the work.

The first board of Michigan consisted of the governor and two appointed members who were to hold office until the expiration of the next regular session of the legislature. Their duty was stated to be "to select a suitable location for a State fish-breeding establishment for the artificial propagation and cultivation of whitefish and such other kinds of the better class of food-fishes as they may direct, upon the best terms possible." They were required to appoint a superintendent of fisheries of the State and to supervise generally the fishing interests and secure the enforcement of all the laws relating to the protection of fish and fisheries in the State. The fact that the whitefish was the only one specifically named in the organic act, indicates the regard the people of the State had for this fish, and it has been often since cited as an argument against any neglect of that branch of the work.

The governor, at the time this legislation was enacted, was Hon. John J. Bagley, of Detroit, whose interest in and appreciation of the work had much to do with the passage of the law, as well as with the public interest in the subject and the early success of the commission. His associates on the first board were Andrew J. Kellogg and George Clark, the latter of whom had an experience of almost half a century in catching whitefish in the waters of the State.

The first board was singularly fortunate in securing as superintendent the enthusiastic and untiring George H. Jerome, whose spicy and vigorous contributions to the literature of the subject, contained in the early reports of the commissioners, have won the admiration of each succeeding board and of every appreciative reader. The salary of the superintendent was limited by the act to $1,200, but the meagerness of the compensation did not hinder him from giving to the work all the energy and ability he possessed. He was the life and spirit of the board so long as he retained his place.

The following words from the first report of the commission are deemed worthy of quotation:

> The water world, subjected year by year to new discovery and to a larger development, may be implicitly relied upon in the years to come to contribute a much larger quota of food than at any preexisting period. This, as viewed from the fish-culturist's standpoint, is believed not to be merely possible, but highly probable. Indeed this is the fish problem, nothing more, nothing less; and to the solution of this problem the veteran band of fish-culturists, with the appliances at hand and with a will and courage equal to every conceivable emergency, have gone to work, resolved not to lay down their tools till every promise of theirs is redeemed and every prophecy fulfilled.

The appropriation for the first two years was $7,500 a year. With this fund the commission established a State hatchery at Crystal Springs, Pokagon, Cass County, on the Methodist camp meeting grounds, and built a hatchery 20 by 60 feet, one story high with a roomy attic, and a small residence for the overseer. The earlier efforts of the commission were devoted somewhat to the propagation and planting of several kinds of foreign fish, the Atlantic salmon, the landlocked salmon, the California salmon, and the shad, and we are constrained to believe that much faith and enthusiasm, as well as labor and money, were wasted in the effort to acclimate these foreigners to the waters of Michigan. The whitefish, however, was never overlooked or neglected.

The first plant of whitefish was in the spring of 1874, and it exceeded 1,500,000, which was greater than the plant of all other kinds. These were hatched at the hatchery of N. W. Clark, at Clarkston, Oakland County.

In the spring of 1875 there were hatched at the State hatchery at Pokagon about 150,000 whitefish, and about 2,000,000 were bought of N. W. Clark & Son, of Northville, at the price of $1 per 1,000. The plant was over 2,200,000.

In the fall of 1876 a small whitefish hatchery, 20 by 50 feet, was built on a leased lot near the waterworks on Atwater street in Detroit, and the experiment tried of using the city water. Oren M. Chase was put in charge of this hatchery. The hatching was done at first in the Holton hatching-box, for the use of which a royalty of $100 a year was paid.

In the spring of 1876 nearly 10,000,000 whitefish were hatched, and the plant in Michigan was 9,310,000. The rather boastful mention of this then unparalleled hatch in the second report of the commission is somewhat amusing in the light of what is now being done in that line.

In the organic act provision was made for coöperation with other States contiguous to the waters of Michigan, which should make appropriations for the work and express a desire for joint action, and in the report of 1876 mention is made that several of the States bordering upon the Great Lakes, notably Ohio, Wisconsin, and Minnesota, "have got sharply to work upon the whitefish."

The planting of salmon trout was begun in 1875, when 150,000 fry were purchased of N. W. Clark & Son, at the price of $2 per 1,000, and planted in the inland lakes of the State. The work on the Atlantic, the California, and the landlocked salmon continued through the seasons of 1875 and 1876. In the meantime Eli R. Miller, of Richland, had succeeded Governor Bagley as commissioner, and was made president of the board, the statute having been so amended as to provide for three commissioners, one for two years, one for four years, and one for six years, their successors to be appointed to a term of six years each. The appropriations for 1875 and 1876 were $7,000 for each year. Twenty-two States were at this time more or less actively engaged in fish-culture.

In 1877 the whitefish plant exceeded 8,000,000. Some experiments were made in hatching the herring and the German whitefish. In the third report the commission congratulates itself that while it had paid $1 per 1,000 for hatching whitefish it now was producing them at a cost of not to exceed 10 cents per 1,000. The Chase automatic jar, an invention patented by Oren M. Chase, had now taken the place of the hatching-box and was the means of greatly cheapening the production.

The hatching of lake trout and of California salmon and landlocked salmon was continued through the years 1877 and 1878, and experiments were made with grayling, though with indifferent success. In 1877 the planting of eels was first inaugurated. They were taken in the Hudson, near Troy, and transported in cans.

In the third report the superintendent concludes the California salmon is too large a fish for the great bulk of the inland lakes and should be planted mainly in the rivers emptying into the Great Lakes. The brook-trout work commenced about this time at the hatchery at Pokagon, the take being from 200,000 to 300,000 eggs.

On October 14, 1877, George Clark died and was succeeded by Dr. Joel C. Parker, of Grand Rapids, who continued as commissioner by successive appointments until January 1, 1893. He held the office of commissoner continuously longer than any other member and gave much valuable work and thought to the subject of fish-culture.

The appropriations for the years 1877 and 1878 were $7,000 a year. Twenty-eight States were now engaged in fish-culture. The plant of whitefish for 1878 was upward of 12,500,000, and for 1879 upward of 14,500,000. During these two years the work on California and landlocked salmon and lake trout and eels continued, and two new varieties, the German carp and the California or rainbow trout, were introduced.

The appropriations for the years 1879 and 1880 were cut down to $5,000 a year. On July 1, 1879, George H. Jerome resigned as superintendent, and was succeeded September 15, 1879, by James G. Portman, of Watervliet, Berrien County, and the only one of the old employés retained was Oren M. Chase, who had been overseer of the Detroit hatchery from its start.

Up to this time a considerable plant of whitefish fry had been made each year in several of the inland lakes of the State. No extensive reports of the favorable results of such planting coming to the commission, the planting was thereafter confined to the Great Lakes and the rivers and straits connecting them, and such interior lakes as contained native whitefish, and thus another undoubted mistake was corrected. The commission, becoming convinced that the brook trout was capable of a much wider range throughout the State than was formerly supposed, began to give additional attention to raising and distributing this popular fish. The fourth report bravely suggests that not less than 1,000,000 brook-trout fry should be hatched yearly for Michigan streams. A few black bass were hatched and planted, and some experiments made in hybridization. Renewed efforts were also made to accomplish something for the grayling, but without success. About this time the few remaining adult California salmon were turned loose; their exit was preceded by that of the Atlantic salmon, and his by that of the shad, and thus was another mistake corrected. The landlocked salmon struggled along a few years later, but his name has since been struck from the list.

In the summer of 1880 the Detroit hatchery was remodeled and the last of the Holton boxes discarded and their places supplied with the Chase jars, giving a total of 300 jars and a hatching capacity of more than 30,000,000 whitefish fry. Six of these jars were exhibited by Prof. Baird at the International Exposition at Berlin, and Mr. Chase secured the "golden medal of honor" for the invention. About this time the trout and salmon in the ponds at Pokagon began to sicken and die, and an analysis of the water demonstrated that it was not suitable for the trout work; and thereupon ground and water was rented at Boyne Falls, where, through the liberality of Hon. Thomas S. Cobb, of Kalamazoo, a temporary hatchery was located. After a season's use, however, the dam was carried away by a freshet and the hatchery abandoned. The carp were retained at Pokagon for a while, but were soon after removed to Glenwood, where the carp-hatchery has since been carried on under the supervision of Mr. Worden Wells, in ponds belonging to him, and with unvarying success.

The whitefish plant for 1880 was 10,695,000, and for 1881 only 3,000,000. The cause of the falling off was the difficulty in procuring the ova on account of storms and the failure of the Detroit river fishery, where the fish had theretofore been obtained. About this time the methods of securing the ova were much improved under the suggestion and experiments of Oren M. Chase, who found it feasible to retain the fish in small crates, through which the water flowed freely, and to handle the fish from day to day and take the eggs when ripe, thus making a great saving of the eggs and resulting in but trifling injury to the adult fish.

In July, 1881, the trout station at Paris, Mecosta County, was located on Cheeney Creek, and about 40 acres of land and the meander of the creek, 15 rods wide, across 120 acres more, were purchased. Here, in the early fall of that year, was built a trout hatchery, 20 by 60 feet, a dwelling-house and barn, and the hatchery and ponds at Pokagon were abandoned.

The principal trout work of the State has been conducted at the Paris station ever since without any serious drawbacks. The work, however, has now about reached the limit of the water supply, and one neighboring stream has already been brought over in pump logs, and it is contemplated doing the same with another.

The whitefish plant of 1882 was upwards of 18,000,000. That spring the experiment was first made with the wall-eyed pike, and a plant was made of 1,120,000.

The board had some difficulty with Superintendent Portman, and in September, 1882, he was succeeded as superintendent by Oren M. Chase. Mr. Chase served until November 11, 1883, when he was drowned in Little Traverse Bay while in the performance of his duties, sacrificing his life in his zeal for the work. Walter D. Marks was then made acting superintendent until March 26, 1884, when he was regularly appointed superintendent, and continued to act in that capacity until the early part of 1893, when he resigned. Mr. Marks was an early pupil of the veteran Seth Green, and was a man of large experience in handling and breeding fish. He was full of resources and always found some way out of every difficulty that beset his work.

January 1, 1883, Eli R. Miller retired as commissioner at the expiration of his term, and John H. Bissell, of Detroit, was appointed his successor. The work had reached a somewhat low ebb at this period and needed just such an energetic, thoughtful, and practical man as he proved to be to give it a new impulse. It is no disparagement of anyone else to say that Mr. Bissell is entitled to as large a degree of credit as anyone for such success as the Michigan Fish Commission has attained.

The appropriation for 1881 was $8,000 and for 1882, $7,500. In the fall of 1883 the work of obtaining accurate statistical information as to the amount and value of the commercial fisheries of the State was commenced in a small way. The whitefish plant of 1883 was 23,735,000 and that of 1884 was 37,750,000. The brook-trout plant of 1883 was 269,000 and that of 1884 was 353,000.

In the sixth report it is again urged that there ought to be hatching-house room sufficient for at least 1,000,000 brook trout. In 1883 a new site was chosen at the corner of Joseph Campau avenue and Lafayette (now Champlain) street for the Detroit whitefish station. This site is 100 feet square. The lots were rented and a hatchery 40 by 80 feet built, with a shop and barn 30 by 46 feet in the rear along the alley. This building cost about $5,600, and was equipped entirely with Chase jars. It held 312 jars with a hatching capacity of about 42,000,000 whitefish eggs. About this time more land was purchased, near the trout station at Paris, and the ponds increased and grounds much improved.

In August, 1883, a whitefish-hatching station was established at Petoskey upon leased grounds; but for various reasons, principally connected with the condition and quality of the water supply, this proved another mistake and a somewhat costly one, too. Without going into detail, suffice it to say that this hatchery, after being used two or three years, had to be abandoned. As early as 1883 a movement was inaugurated toward the establishment of a whitefish and trout hatching station upon Lake Superior, but it did not result in anything tangible until several years later.

In October, 1883, a meeting was held at Detroit of the fishery commissioners of the States bordering the Great Lakes, upon invitation of the Michigan Commission. Commissioners attended from Minnesota, Wisconsin, Ohio, and Michigan, and a representative of the U. S. Fish Commissioner was present. A movement to secure uniformity of legislation led to the consideration of the subject of Federal supervision of the fisheries of the Great Lakes. At the request of the Michigan Fish Commission, Mr. Otto Kirchner, then attorney-general of the State, examined the authorities and presented an able brief to the effect that the Federal Government had no jurisdiction of the subject, and that such protection as was had must come from the authorities of the several States. This conference was productive of much good feeling and undoubtedly helped on the work of uniform legislation of the several States bordering the Great Lakes for the protection of the fishing interests.

In February, 1883, a secretary of the board was appointed for the first time. Herschel Whitaker was designated, and served until June 1, 1884, when he resigned, and Andrew J. Kellogg succeeded him. Mr. Kellogg served until March 20, 1888, when he was succeeded by George D. Mussey, who has served ever since. On the resignation of Mr. Kellogg as commissioner to take the appointment as secretary, Mr. Whitaker was appointed commissioner in his place and has continued in office to the present time. The combination of Mr. Whitaker, Mr. Bissell, and Dr. Parker made a strong board, and from this time on a new impetus was given to the work. The business was organized and the work classified and systematized as it never had been before. Through their influence larger appropriations were obtained and the work extended in every department.

The commission in 1884 obtained control of one of the fisheries on the Detroit River, and this policy has been extended until now they control all the fisheries on the American side of the river.

The sixth report sums up the condition of fish-culture in 1884 as follows:

> The present aspect of this subject is far different in many respects from what its advocates and promoters of ten or more years ago believed it would be at this time. The general enthusiasm of the early movement, as it seized upon the naturalist and sportsman of ten or fifteen years ago in the blush of its first successful experiments, has not entirely faded away, but has ripened into a deep conviction on the part of an ever-increasing number of intelligent men that fish culture has solved one-half of the question, "Can the fisheries be preserved?" and has now settled down upon business-like principles and methods to do its part. The other half of that question must depend for its answer upon wise measures for protection. This is true of almost every State and Territory in the Union.

The appropriations for 1883 and 1884 were $10,000 for building and equipping new stations, and $10,000 a year for current expenses.

In August, 1885, Mr. Lyman A. Brant was appointed statistical agent for the board, and visited all the commercial fisheries of the State and made a full report in writing of his work, which was much the best of its kind that had thus far been done, and afforded the commission much needed information.

The whitefish plant for 1885 was 40,000,000, and for 1886 was 61,620,000. A few Loch Leven trout were planted and the plants of California trout were continued, but the adult fish did not do well in the stock ponds and many of them were liberated. Further experiments with grayling were made; a large portion of a grayling stream was stocked with them and barriers erected to prevent their escape and every inducement provided for them to spawn in a semiwild or natural state, but the experiment was a failure. Additional ponds were built at the Paris station, and the grounds other wise improved by grading and sodding. Further agitation was given to the question of the Upper Peninsula whitefish station. A scheme of systematic examination of all the inland waters of the State, seriatim, was inaugurated. For this purpose a double crew of men was sent into the field and charts of each lake examined were made and filed in the office, to be bound into books. These charts contain a rough sketch of the shape of the lakes, give their name and location, dates of examination, kind of bottom and shores, temperature at top and bottom, soundings, number and kinds of fish caught and how, their condition and what feeding upon, the kinds and condition of fish food in the water, and recommendation as to kinds of fish to plant. This work has been continued each year until at present there are complete records of upwards of 400 lakes which have been examined, the reports of which are bound together in volumes indexed and easy of reference. These volumes are consulted in passing upon applications for fish plants in the waters.

The capacity of the trout-hatching house at Paris has already reached 1,500,000, and a new house is recommended to increase the capacity to 3,500,000.

The hatching and planting of whitefish, brook trout, lake trout, wall-eyed pike, carp, Loch Leven trout, landlocked salmon, and California trout continued through the years 1887 and 1888. In 1887, the first plant of German trout was made and the rearing of this fish has been continued ever since and much increased in later years. It seems to thrive in Michigan waters and has every appearance of being a hardy and vigorous importation.

In 1887, an additional trout-hatching house, 40 by 82½ feet, was built at Paris at a cost of about $4,000 for the house and fittings. The old hatching-house was dismantled, but remains standing and is used for a storehouse and shop. It is capable of being restored and put in use again on short notice and at small cost, if needed. The capacity of the Detroit whitefish house was increased by the addition of the jars removed from Petoskey, so that it contained 525 jars, which would hatch 80,000,000 to 90,000,000 whitefish a year.

In 1888 the commission had a car built for transporting fry and fish. It is over 55 feet long and substantially built, with passenger-coach trucks, air brakes, platforms, coupler, and buffers, so that it can be easily hauled in any passenger train. It has an office at one end and a kitchen at the other, and is fitted with five berths, enabling the men to live and sleep on the car. Its capacity is 175 cans. It is named "Attikumaig," the Chippewa name for whitefish, meaning literally the "deer of the water." This car has proved a great convenience, and has been the means of cheapening the distribution of fish and fry. It has been in continual use from February till the latter part of June of every year since it was built. The plant of whitefish in 1887 was 72,984,000, and in 1888 about the same number. The brook-trout plant in 1887 reached 1,000,000, and in 1888 was over 1,500,000. The wall-eyed pike plant of 1887 was 3,280,000, and in 1888 it was 11,492,000.

Mr. Bissell's term of office expired January 1, 1889, and Hoyt Post, of Detroit, was appointed his successor. On March 20, 1888, Mr. Kellogg resigned as secretary, and the present secretary, George D. Mussey, succeeded him.

In 1888 and 1889 the secretary made trips of investigation of the fisheries and filed written reports, which are printed in the biennial reports of the commissioners. In January, 1890, Mr. S. C. Palmer continued this work on a more extended scale. During the years 1891 and 1892 Mr. Charles H. Moore engaged in similar work for the commission and obtained complete reports of every fishery in the State, his work being as complete as could be made. Experiments were made in hatching sturgeon eggs, and a few were successfully hatched. A successful hatch was also made of the eggs of white bass. These eggs are very small and hatch in about 48 hours. Subsequently larger quantities were successfully hatched in the Chase jar.

The commission has made several fish exhibits, embracing nearly all varieties of native fish, at the State Fair and Detroit Exposition and elsewhere. These exhibits were comparatively inexpensive and were very attractive and proved valuable aids in disseminating knowledge of fish and fish-culture. The report of 1890 was the first illustrated report issued. It contains cuts illustrating the hauling of the seine and the stripping of fish, and interior and exterior views of the hatcheries, and of the ponds and grounds at Paris, adding much to the attractiveness of the report.

Some attention now began to be given to scientific work, and Prof. Jacob E. Reighard, of the University of Michigan, began his investigation of the development of the wall-eyed pike. The motive that first led to this investigation was the discovery of the cause of the large percentage of loss in hatching the eggs of this fish as compared with those of the whitefish. He made extended microscopical examinations and accompanied the men in the field and followed the eggs to the hatchery and watched their development and hatching. He reduced his observations to writing, furnishing an article of upward of 60 pages, with microscopical drawings, which was published in the ninth report, with plates of the drawings. This article is regarded as an exceedingly valuable contribution to the literature of fish-culture and has been in great demand. Prof. Reighard also conducted like experiments with whitefish eggs. He also accompanied the crews for examination of waters with his microscopes and an assistant and a botanist, and made quite extensive examinations of the fish food and aquatic plants, and incidentally of some fish-parasites. He also prepared a still more elaborate article on the development of the embryo of the wall-eyed pike, covering about 80 pages, which, with the plates illustrating it, are published with the tenth report. He is at present inaugurating some experiments connected with the food of the whitefish and its life and abundance and when and how distributed, which it is hoped will be of value in determining the proper places for planting the whitefish fry. It is designed to make this examination as careful and exhaustive as the means at hand will allow, and it is planned to interest the authorities of the University of Michigan to coöperate with the commission in extending work of this scientific nature from time to time. No work of the commission has attracted wider attention among intelligent readers than the work already done by Prof. Reighard.

A boiler and pump were added to the Detroit hatchery for use in case of an emergency causing the stoppage of the flow of the city water, such as had been once or twice experienced. By this means the water in the storage tanks could on short notice be pumped up into the troughs which feed the hatching jars and keep the water circulating through the eggs until the stoppage of the regular flow of the city water ceased. The storage-tank capacity of the hatching-house was also nearly doubled by enlarging the wing of the building.

In the summer and fall of 1889 the efficiency of the Detroit whitefish hatchery was doubled by the erection of two additional frames of jars, which increased the number of jars in place to 1,050, with a hatching capacity of nearly 200,000,000; but the difficulty of obtaining sufficient ova to fill the jars prevented for a year or two reaping the full benefit of the increased capacity. The whitefish plant in 1889 was 63,000,000, and in 1890 it was 100,750,000. The wall-eyed pike plant of 1889 was 44,340,000, and in 1890 it was 22,300,000. The brook-trout plant of 1889 was 2,468,000, and in 1890 it was 2,578,000. The appropriations by this time had increased to upward of $20,000 a year, and the inventory of the property of the commission showed a valuation of upward of $35,000.

The tenth report covers the years 1891 and 1892, and is a substantial volume of 228 pages. In the fall of 1891 a small hatchery for whitefish, lake trout, and brook trout was established at Sault Ste. Marie, containing 200 jars, besides such hatching troughs as the space in the building would admit. The city paid the rent of a small store building in which this hatchery was set up, and furnished city water free. This hatchery was run during the seasons of 1891 and 1892, but, owing to difficulty and disappointment in procuring whitefish ova, was not filled until 1892. The purpose of a whitefish hatchery on Lake Superior was to provide for stocking that great lake, the hatch at the Detroit house coming on too early to be planted, on account of the ice in the harbors. It was thought that the difference in the temperature of Lake Superior water would retard the hatch about two or three weeks, which proved to be the fact. The water at the Sault proved admirably adapted to the work of hatching both whitefish and brook trout. The temperature of the water is remarkably even and cold. It began November 15 at 42°, and for the month ensuing varied from 42° to 38°, and about January 1 ran down to 34°, where it remained without over 1° variation either way until April 26, and from then until May 15 it did not go above 40°. A daily record of the temperature of the water is kept at each station while in operation.

The appropriation for 1891 and 1892 exceeded $27,000 a year, and those just granted for the years 1893 and 1894 are $25,000 a year. The inventory of the property has increased to nearly $38,000.

Never till the fall of 1892 had the Detroit hatchery been completely filled with eggs. In that year the commission controlled all the fisheries on the Michigan side of the Detroit River, and instead of letting them out to others to fish, hired the fishermen and absolutely controlled and directed the fishing.

Through the energy, persistence, and skill of the superintendent, W. D. Marks, in conducting this work, more fish were caught and more eggs taken than ever before. The total of whitefish caught was 13,074; the total eggs taken was 4,544 quarts, or 142 bushels, making 173,630,400 eggs. It was a beautiful and inspiring sight to look upon the tiers of jars in the Detroit house, more than a thousand in number, all filled and in active operation. It was a sight never equaled elsewhere and but once there.

The whitefish hatchery at Detroit is undoubtedly the largest, best arranged, best equipped, most economical, and most efficient in the world. No other has begun to compete with it in output. And there are few if any brook-trout hatcheries that excel the one at Paris. The whitefish eggs are placed in the jars in November and December, and remain from 130 to 140 days, or until March and April, before they hatch, and the fry are no more than out of the way before the same jars are filled with the eggs of the wall-eyed pike, which are placed in the jars in April and May and hatch in 28 or 30 days, coming out the last of May and first of June.

It has been the habit of the board for the past few years to hold regular monthly meetings and such special meetings as may be found necessary, and full records are kept in writing, in bound volumes, of the proceedings, including everything of interest in fish-culture which comes to the attention or knowledge of the members from time to time. Full books of account are kept of all the money transactions. All payments are by checks signed by the member of the auditing committee who certifies to the account, and vouchers in duplicate are taken for all payments. William A. Butler, jr., of Detroit, has been treasurer of the commission since about 1883.

Bound volumes are kept of the statistical reports and examining crews. All applications for fish are in writing on printed blanks furnished, which describe the location and character and temperature and soundings of the water, and the surroundings where it is proposed to plant the fry.

In January, 1893, the term of Dr. Parker expired and Horace W. Davis, of Grand Rapids, was appointed his successor.

In December, 1892, an international fish conference was held at Detroit under the auspices of the Michigan Commission. There were present Samuel Wilmot, of Ottawa, Canada; Edward Harris, of Toronto; Thomas Marks, of Port Arthur, and W. B. Wells, of Chatham, Ontario, and members of the fish commissions of New York, Ohio, Minnesota, Maine, and many others from different States, including some fishermen. The subjects discussed were connected with uniformity of legislation protecting fish and game, and more particularly the vital question of a close season for the commercial fish. The main results of the meeting were embodied in a report of a committee which was adopted, as follows:

1. That all small fish and others unfit for food, of all kinds, when taken in nets, should be replaced in the waters when taken alive; that fishermen should not be allowed to take such fish on shore nor expose them for sale.

2. That no strings of pound nets used in the lakes shall extend more than 4 miles from shore.

3. That one-half part of all channels between islands or elsewhere, where fish migrate to spawn, shall be kept free from nets of all kinds at all seasons.

4. That all whitefish taken of less than 16 inches in length, and all salmon trout less than 2 pounds in weight, shall be immediately returned to the waters where taken and shall not be exposed for sale.

5. That the month of November in each year be made a close season for whitefish, herring, and salmon or lake trout.

6. That all penalties fixed for violation of any laws that shall be enacted shall be made not only to apply to those who take fish, but also to all persons who buy, sell, transport, or have the same in possession.

The following resolution was also passed, viz:

Resolved, That the law should authorize the seizure and destruction of nets which are used in violation of law.

Throughout all the ten reports of the commission are frequent acknowledgments of courtesies and exchanges with the commissions of other States and especially with the U. S. Fish Commissioner, to whom the Michigan Commission is under very many obligations for continued favors and grants of eggs and fry and fish of varieties that could not be elsewhere procured.

The Michigan Commission would be guilty of ingratitude and lack of appreciation if it ever permitted any account of its work to go forth without due acknowledgment of its obligations to the railroads of the State, without whose aid, given for the asking and without stint, it could never have accomplished anywhere near what it has.

Ever since the organization of the commission it has at each legislative session given much time and attention to procuring the passage of proper protective legislation to preserve the fisheries; but it seems much easier to get legislation through to propagate fish than to lay any restrictions upon the catching. As against any such restrictions an active lobby always appears on the scene and cries out about the ruin and destruction of property and investments, and who ever knew a legislature that was proof against such a plea.

From the annexed table it will appear that the total plants of whitefish aggregate the large number of nearly 750,000,000, commencing in 1874 with little above 1,500,000. The 20,000,000 point was not reached until 1883, the 50,000,000 point until 1886, nor the 100,000,000 point until 1890, so that more than half the whole number have been planted within the past five years.

It is matter of deep regret to everyone connected with or interested in the artificial propagation of whitefish that actual and tangible demonstration of the results of such large plants can not in the nature of things be obtained. The results of brook-trout planting in streams are so open to inspection and so easily observed and appreciated that it is not difficult to convince any caviler by proofs and demonstration that can not be gainsaid; but to reason from analogy it would seem that if the relatively smaller output of brook trout has produced such remarkable results as they are known and acknowledged to have, the millions of whitefish and wall-eyed pike that have been planted in the Great Lakes must have made a marked impression on the commercial fisheries, and yet frankness compels the admission that thus far the increased catch of adult whitefish is not at all commensurate with what it seems ought to have been expected as the outcome of these great plants. It is true there are many

things to be taken into account in this matter, not the least of which is the slaughter of immature fish; but it would be very gratifying if the actual outcome of these plants could be proved as it can with the plants in the streams.

Fish planted in Michigan waters, 1873-1892.

Year.	Brook trout.	Whitefish.	Wall-eyed pike.	Carp.	Atlantic salmon.	California trout (fry).	Swiss lake trout.
1873					21,350		
1874		1,532,000			139,000		
1875		2,211,500					
1876		9,310,000					
1877		8,001,000					
1878		12,520,000					
1879	12,000	14,545,000					
1880	50,400	10,695,000				12,000	
1881	388,500	3,000,000		1,093			
1882	251,000	18,170,000	1,120,000				
1883	219,000	23,735,000					
1884	353,000	37,750,000	2,040,000			6,000	
1885	408,000	40,000,000		2,088		25,000	
1886	719,000	61,620,000	1,806,256	3,422			
1887	1,090,000	72,984,000	3,280,000	2,843		20,000	
1888	1,639,000	72,968,000	11,492,000	3,878			
1889	2,468,000	63,000,000	44,340,000	3,490		4,000	
1890	2,578,000	109,700,000	22,300,000	5,798		*16,000	17,360
1891	2,500,000	104,000,000	27,045,000	2,231			
1892	2,422,000	†65,500,000	57,300,000	2,025			
1892		‡9,724,000					
	15,097,900	740,965,500	170,723,256	26,868	166,350	83,475	17,360

Year.	Loch Leven trout.	Brown trout.	Lake trout.	California salmon.	Schoodic salmon.	Eels.	Black bass.	Bass.
1873				45,900				
1874				419,930				
1875			150,000	323,000				
1876				227,000	20,300			
1877			168,500			265,000		
1878			433,834	73,000	26,000	405,000		
1879			379,000	215,246	4,867	317,000		
1880			26,500	§575	20,000		3,500	
1881						390,000	7,000	
1882					13,517			
1883					27,874	236,000		
1884								
1885	8,000		215,000		48,000	325,000		
1886			490,000		23,000			
1887					23,636			
1888	5,000				73,424		1,560	
1889		20,000	‖13,000		5,000			
1890	30,000	60,000	‖467		44,000		185	
1891		156,000				273,000		2,500,000
1892		271,500	‡204,000					
	43,000	507,500	2,080,301	1,304,651	329,618	2,211,000	12,245	2,500,000

* Also 475 adults. † From Detroit station. ‡ From Sault Ste. Marie station.
§ Adults. ‖ 2 years old.

23.—HISTORY AND METHODS OF WHITEFISH CULTURE.

BY FRANK N. CLARK,
Superintendent of U. S. Fish Commission Station at Northville, Michigan.

The history of fish-culture is claiming the public attention as never before. From earliest time the art has been rife among all peoples, even among the more rude and uncivilized. We read of the fisheries of Byzantium, old Constantinople, that were both lucrative and extensive. The fisheries of Rome in the vicinity of Sicily and in the Carpathian Sea and those of the ancient Egyptian inland lakes are all of historical interest. Egyptian fisheries were protected by the most stringent laws. The revenues of the fisheries of Lake Maerie amounted to more than $500,000 annually, which is evidence of their extent. Early in the ninth century laws went into effect in western Europe touching the immense European fisheries. But while fish have been used as an article of food since the dawn of the race, pisciculture never reached its practical and scientific position till more recent years.

The Chinese practiced the art of rearing and fattening fish in confined bodies of water, by placing twigs in the water during the spawning time of carp and removing them when covered with the spawn. The Romans followed a like method, while the Egyptian pictorial relics show a similar custom, a large vivary being built and maintained for the purpose of growing fish for table use and religious sacrifice. The historian of ancient Rome tells us of the extensive and complete fish ponds of the Romans. The Roman Hortensius was more concerned about his mullet than his men, and his fish servants were for number almost countless. He employed sailors to procure food for them, and when the weather prevented the tars from leaving port in search of fish food, butchers and provision dealers would bid for supplying the fish with provender. His head man, or "nomen-clator," not only gave a name to each individual fish, but taught them to "wag their tails, fawn like dogs, and permit themselves to be scratched and clawed," when exhibited to visitors. There is much fable concerning the affection of the Romans for individual fishes, but the fact that they were successfully reared is well established. This, briefly, is the general character of ancient fish-culture. It did not include what the culturist of to-day considers the most skillful item of his work—the taking of the eggs from the female fish, impregnating, and hatching them.

As early as 1741 Stephen Ludwig Jacobi, a young German, discovered this art and successfully practiced it years before making it public. Since then, with various changes and improvements in methods, it has been in vogue in different countries, but nowhere has larger success been obtained than in the United States. When in 1880 the International Fishery Exhibition occurred in Berlin, which was one of the most notable events in fish-cultural history, the grand prize was awarded this country for the best collection illustrating the fisheries, while the United States captured six out of ten gold medals awarded, Germany securing three, and Russia the remaining one.

And so the history of our profession has had its birth and growth, and is of vital interest to those who care for these matters. With this general introduction I turn to briefly consider the history of whitefish culture from the beginning of the work to the present, with methods, apparatus, etc.

The first intimation we have of the artificial work with whitefish is found in a paper by Mr. Milner, deputy U. S. Commissioner of Fisheries, on "The History of Fish Culture," in which he says:

> In November, 1857, Mr. Carl Miller, of New York, and Mr. Henry Brown, of New Haven, Conn., visited Lake Ontario, and, taking males and females of whitefish alive from the nets of the fishermen, impregnated a large number of eggs, estimated by them at 1,000,000. They were packed in alternate layers with fine wet sand, presumably in a box, but not stated, and transported to Saltonstall Lake, Conn., and there deposited upon sandy spots in the lake. The eggs had the appearance of being in good condition when they arrived at their destination. In March and April following, the young were said to have been seen in large numbers. Again, in 1858, 10,000,000 ova of trout and whitefish were obtained and placed in the lake, and considerable numbers were believed to have been hatched.

Mr. Milner notes that the numbers were probably overestimated in both cases.

From the Maine commission report for 1870 we find that in November, 1868, they laid down in the hatching troughs for experiment a number of whitefish eggs, and in the following March and April a large number of young fry made their appearance. The fry escaped to a stream below the hatchery, and later in the season whitefish of 4 to 5 inches in length were noticed and some shown at the Provincial Show at London

The first successful series of tests were begun in 1868, by Seth Green and Samuel Wilmot in applying artificial culture to this species, and in the succeeding year by my father, Mr. N. W. Clark, with whom I was associated at that time.

Mr. Milner further says:

> They were found to be very delicate and difficult to hatch in the first few years of experimenting, but methods were perfected that made their production as certain and losses nearly as small as in other species.

From this it will be noticed that Mr. Wilmot and Mr. Green began their experiments one year previous to my father and myself. I have not been able to obtain the facts as to Messrs. Green and Wilmot's plan of handling the eggs, but it may be presumed that it was carried forward in a manner similar to our own.

Commencing, then, with the fall of 1869, we find that Mr. Clark, through the courtesy of Mr. Green, obtained 50,000 whitefish ova and placed them in gravel hatching-boxes fed by spring water at the temperature of 47° F. It was found they required much closer attention than trout ova and the constant removal of the dead eggs was necessary to avoid the growth of fungus, the whole becoming one mass of vegetable mold. However, 2,000 were hatched and through the wire mesh escaped into a lake below the hatchery.

Again, in 1870 a like number was obtained through the courtesy of Mr. George Clark, of Ecorse, Mich., placed in the same troughs with the same temperature of water. A much larger number were hatched, bursting the shell about January 15 to January 20. By the use of finer-mesh wire the young fry were retained in the troughs. Soon after the hatching Mr. J. W. Milner, deputy United States Commissioner, visited the hatchery at Clarkston and took some one hundred of the fry with him to his home at Waukegan, Ill., to experiment, and, if possible, learn the food of the whitefish; some 3,000 were retained in the troughs, but later they all died, only surviving four weeks.

In the fall of 1871 a larger hatchery was erected further down the stream, and a dam constructed, flowing over a large area, for the purpose of cooling the water. My father's experiments led him to believe the eggs should be retained to such a time as would seem to be more nearly the natural hatching time of the eggs spawned in the Great Lakes. Through the courtesy of Mr. John P. Clark and George W. Clark, he was able to obtain upwards of 500,000, a fair percentage of which was hatched and planted near the hatchery and Detroit River.

Again, in 1872 a fair number were obtained, hatched, and planted, a portion being carried forward for the U. S. Fish Commission. An estimate, by Mr. Milner, of good eggs, placed them at 66 per cent; the first considerable shipment of eyed eggs was made to California from the Clark establishment by Mr. Milner, the deputy commissioner.

In 1873 the take was 800,000. Experiments were inaugurated with reference to the growth of the fish. Eggs were hatched in spring water in sixty days, and by a series of mixing the spring and ice-cold waters from the creek, it was possible to bring fry out weekly. From January 15 to April 1 weekly hatch experiments were conducted with regard to growth. Success was not very marked, however, till toward the last of the hatching. The fry produced after March 15 seemed stronger, and from this lot we find that by June 18 those in the lake water had reached a length of 1½ inches.

As to the apparatus in use for transporting the eggs from the fishing-grounds on the Detroit River to the hatchery at Clarkston, I quote from Mr. Milner:

> An improved case for the carriage of eggs long distances by railroad is another device perfected by Mr. N. W. Clark in 1872. It is a modification of the ordinary case containing circular cups, the cups being square, and in this form economizing space very much. The cups of tinned iron, about 4 inches square and 2 inches high, rest in trays with low partitions forming low compartments that retain the bottom of each cup and hold it solidly in place. The trays are set within a square tin box, in which they fit with moderate tightness, and are placed, when containing the cups, eight or ten in a box, one above the other; this box is set within another box of tin large enough to leave an open space on all sides, to be filled with sawdust; a tube is inserted through the bottom of the inner box, piercing the bottom of the outer one, so as to permit communication with the air on the outside; the whole is then placed for protection within a strong wooden box, in the bottom of which is a frame resting upon stiff springs which relieve the eggs from heavy jarring; rubber or cloth bumpers on the sides of the box prevent lateral swaying and jolting. A cover is fitted on the inner box, which may then be covered with sawdust to the level of the higher outer one, when the cover of this is to be shut down. The outside wooden box is fitted with handles and with a tight lid on hinges, which may be locked. Small auger holes are bored through the outer or packing box and air may be admitted to the whole interior of the egg case through the tube referred to in the bottom, the cups being pierced with small holes, so that when placed they are directly over circular openings in the trays and a communication of air is established throughout.
>
> The eggs may be packed in moss, in the ordinary manner, in the cups, which experience seems to prove to be the best manner for long journeys.

The fall of 1874 brought out the flannel trays for transporting eggs from the fishing shore to the hatchery. These were used by Monroe A. Green and my father, for carrying the whitefish eggs to their respective hatcheries. A model of this carrying tray and box may be seen in the Fish Commission exhibit. In transporting whitefish and lake trout-eggs from fishing-grounds to the hatcheries, this apparatus has been continually used to the present time, as no other carrying device has met with the success and convenience of these trays.

During the winter a small number of whitefish eggs were carried forward as an experiment in the hatching of whitefish eggs, which were laid in single layers of woolen cloth stretched on very thin frames of wood, packed in a box imbedded in moss within a refrigerator, and the whole kept by ice at a temperature a little above the freezing point. Mr. Milner notes that "the eggs are left entirely undisturbed after they are first arranged; the only care on the part of the attendant is to keep the temperature above the freezing point." It is true the eggs necessarily occasioned very little care. Once in two or three weeks the trays were overhauled and dead ova removed. Very little confervoid growth appeared, and in March the eggs were removed to hatching trays, where, in a very few days, the fry hatched. Other experiments were tried at this time, such as placing the eggs in fine sand with a drip of water falling on the case containing the sand and eggs. This period, up to the spring of 1873, is what I term the first stage in whitefish hatching.

We now come to the invention of the Holton, Clark & Williams box, a description of which you are all familiar with, and a model of which may be seen in the exhibit. The Clark box was used successfully in hatching some 2,000,000 whitefish during the winter of 1873–74, at which time my father and myself were engaged in hatching for the Michigan Fish Commission, thus inaugurating the work of turning out whitefish by the State. I quote from the Michigan Fish Commission report of 1874:

> During the winter of 1873–74 there were hatched at Clarkston, Oakland County, under the auspices of the fish commission, upwards of 1,500,000 of whitefish. The eggs were laid in the latter part of November, 1873, and commenced hatching the latter part of February. The hatching operations at Clarkston last winter were eminently successful and have established, beyond all cavil or doubt, the absolute feasibility of multiplying, to any desired limit, the whitefish, the acknowledged queen of the lakes.

The Holton box was not used to any great extent until the season of 1875–76, when the Michigan Commission placed them in a newly constructed hatchery located at Detroit, Mr. O. M. Chase, superintendent. The work of laying in the eggs and hatching was very successful, and a large number were deposited in numberless lakes and the Detroit River.

The Clark box was used the same season in successfully turning out upwards of 2,000,000 for the U. S. Fish Commission.

The tray-box method of Holton, Clark & Williamson was of great importance in economy of space, in the facility of manipulation of the eggs, and in saving expense, because smaller buildings were sufficient for the accommodation of the apparatus, from the compactness of which more labor can be accomplished than with the extended trough method.

The shipment of 216,000 whitefish eggs made by the U. S. Fish Commission early in February was not successful, as they arrived in bad condition. This lot was packed upon alternate layers of sponge and eggs, the whole surrounded with fine sawdust. Early in March another shipment was made of 116,000, which arrived in good condition, being packed in moss.

We now pass from the tray-box method to the more compact form of bulk hatching. During the season of 1875–76, Mr. Oren M. Chase, of the Detroit establishment; Mr. Welsher, of Wisconsin, and Mr. Samuel Wilmot were at work on a bulk hatcher for the whitefish. Messrs. Chase and Wilmot continued these experiments, and the use of the Chase jar has become quite general, notably with the States of Michigan and Wisconsin. Up to the period of bulk hatching of whitefish eggs the dead and fungused eggs were removed by tweezers, and it was necessary to devise some method by which the bad eggs might be removed automatically and thus lower the cost of production. By the tray method whitefish fry in 1874 and 1875 were costing from 50 cents to $1 per 1,000, but by the bulk hatchers the cost has been reduced to from 5 to 15 cents per 1,000. The Chase jar was somewhat modified and successfully used by myself in the Northville establishment in 1877.

Other devices have been invented for handling whitefish, such as the Bower trough hatcher, and a hatcher consisting of tin, devised by Mr. Holt of New York State; but none of the devices, to my knowledge, has been used to any great extent. The Chase and Clark jar (a modified Chase jar) were practically the only ones used up to about 1880, when the McDonald jar was invented for the hatching of shad, from which time the McDonald jar has taken the front rank with that of the Chase jar for hatching whitefish, being used in the Put-in-Bay hatchery, the Alpena hatchery, and, I think, at the hatchery at Erie, Pa. Since the invention of these jars they have practically brought the hatching of whitefish almost to perfection, and no practical invention has been brought out to take their place or supersede them.

GROWING WHITEFISH.

To my knowledge, the first whitefish grown that were held for rearing, to amount to anything, was in 1882, when at Northville we held some few thousands of the fry, of which we succeeded in raising several hundred to be one year old. These fish were raised entirely upon chopped liver, and we kept them at the Northville Station until they were large enough to spawn. We have taken the eggs from the parent and hatched them in the automatic jars. In packing and shipping whitefish eggs since 1876 we have practically followed the same plans each season, namely, that of the flannel-tray method, and in shipping to long distances, such as New Zealand, Mexico, etc., the tray has been packed in a refrigerator box.

It is a rare thing nowadays to find any of our shipments of eggs arriving at their destination in poor condition, hardly an instance in a season. The work of collecting eggs is practically carried on after the same method as in the beginning, with the exception of certain localities where the fish, after being caught, are held in crates till ready for manipulation. The work of the Michigan Fish Commission in collecting their whitefish eggs is almost wholly upon this plan. Whitefish fry have been planted in our great lakes from 10,000,000 upwards to 60,000,000 each season since 1876, and it is to be regretted that the increase of whitefish in these lakes has not been larger. The cause has not yet been satisfactorily demonstrated. The fish are planted in the same time of the year that the eggs naturally spawned are supposed to hatch. They are also planted upon the natural grounds where the fish spawn, and still the increase is not so great as we might suppose.

Since 1876 there have been planted in the Great Lakes and inland waters throughout the United States by the U. S. Fish Commission 677,176,000 whitefish fry. The majority of these have been planted in the Great Lakes, and by Canada and the States of New York, Ohio, Michigan and Wisconsin there has, undoubtedly, been planted double this number, and it would seem proper that the time has arrived when we should see if there might not be some better means for introducing the fry in the Great Lakes especially. It is true that in some few of our inland lakes throughout the United States the whitefish planted have done remarkably well, but for our Great Lakes some new method must be adopted for introducing the fish in the waters.

Statement of the distribution of whitefish eggs and fry by the U. S. Commission of Fish and Fisheries, from 1872 to 1893.

EGGS.

Assignments.	1872.	1873.	1874.	1875.	1876.	1877.	1880.	1881.	1882.	1883.	1884.
State fish commissions.											
California	332,000	25,000	20,000	100,000	250,000	500,000	500,000	750,000	500,000		
Maine							1,000,000				
Iowa							500,000	500,000		1,200,000	1,000,000
Minnesota							250,000		5,000,000	5,000,000	20,000,000
Kentucky							500,000				
Nevada							25,000				
New Jersey								100,000			
Connecticut								10,000			
Maryland									150,000	200,000	1,000,000
New York									1,000,000	1,000,000	1,000,000
New Hampshire									200,000	200,000	200,000
North Carolina									250,000	500,000	
Pennsylvania									2,000,000		
Wyoming											250,000
Private applicants.											
Wisconsin				100,000							
Pennsylvania							100,000				
Missouri											50,000
Foreign countries.											
Germany							250,000	312,000	510,000	1,000,000	1,500,000
France								250,000	200,000		
New Zealand										1,000,000	
Australia											1,000,000
England											250,000
Switzerland											500,000
Total	332,000	25,000	20,000	200,000	250,000	500,000	3,125,000	1,922,000	9,810,000	10,100,000	26,750,000

Assignments.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	Total.
State fish commissions.									
California									2,977,000
Maine									1,000,000
Iowa									3,200,000
Minnesota	15,000,000	10,000,000	10,000,000						65,250,000
Kentucky									500,000
Nevada									25,000
New Jersey									100,000
Connecticut									10,000
Maryland	500,000								1,850,000
New York	1,000,000	1,000,000	1,000,000		1,000,000	4,000,000		5,000,000	16,000,000
New Hampshire	500,000								1,100,000
North Carolina									750,000
Pennsylvania	16,500,000	10,000,000	15,000,000	24,400,000	10,000,000	14,000,000	12,500,000		104,400,000
Wyoming	500,000								750,000
Delaware	800,000	1,600,000		1,000,000	1,000,000				4,400,000
Wisconsin				5,000,000	6,000,000	10,000,000			21,000,000
Indiana					10,000	125,000	100,000	200,000	435,000
Ohio						47,500,000	8,000,000		55,500,000
Private applicants.									
Wisconsin									100,000
Pennsylvania									100,000
Missouri									50,000
Foreign countries.									
Germany	2,000,000	1,000,000		100,000		100,000			6,772,000
France									450,000
New Zealand	1,000,000	1,500,000							3,500,000
Australia									1,000,000
England	2,000,000	2,500,000		150,000	200,000	200,000	100,000		5,400,000
Switzerland	1,000,000						100,000		1,600,000
Total	40,800,000	27,600,000	26,000,000	30,650,000	18,210,000	75,925,000	20,800,000	5,200,000	298,219,000

Statement of the distribution of whitefish eggs and fry by the U. S. Commission of Fish and Fisheries, from 1872 to 1893—Continued.

FRY.

Waters stocked.	1876.	1879.	1881.	1882.	1883.	1884.	1885.	1886.
Lake Erie *	1,000,000		2,250,000	4,750,000	7,000,000	12,000,000	25,000,000	15,000,000
Lake Michigan	130,000		5,000,000	7,500,000	11,000,000	20,000,000	25,000,000	29,000,000
Lake Huron			2,000,000	2,000,000	16,000,000	27,500,000	34,000,000	30,000,000
Lake Ontario				3,500,000	9,000,000	6,000,000		12,000,000
Lake Superior					4,000,000	6,000,000	4,000,000	6,000,000
Inland lakes of Michigan	1,340,000					500,000		
Inland lakes of Iowa	100,000							
Inland lakes of Indiana	100,000		15,000					
Inland lakes of New Jersey		90,000						
Nebraska waters					400,000			
Potomac River						1,600,000	1,550,000	2,000,000
Total	2,670,000	90,000	9,265,000	17,750,000	47,400,000	73,600,000	89,550,000	94,000,000

Waters stocked.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	Total.
Lake Erie *	12,000,000		40,700,000	31,028,000	10,000,000	6,000,000	22,370,000	188,598,000
Lake Michigan	17,000,000	1,000,000	3,000,000	6,000,000	4,500,000	4,000,000	2,000,000	135,130,000
Lake Huron	30,000,000	15,000,000	20,320,000	24,400,000	14,560,000	10,750,000	11,140,000	255,670,000
Lake Ontario	3,000,000	2,912,000	4,595,000	3,800,000	3,312,000	3,990,000		52,109,000
Lake Superior			8,000,000	24,850,000	13,830,000	16,727,000	10,627,000	94,034,000
Straits of Mackinac					2,500,000		1,500,000	4,000,000
Inland lakes of Michigan	70,000	2,000,000				2,000,000	2,000,000	8,410,000
Inland lakes of Wisconsin						2,000,000		2,000,000
Inland lakes of Iowa								100,000
Inland lakes of Indiana				100,000				215,000
Inland lakes of New Jersey								90,000
Inland lakes of Idaho			3,250,000					3,250,000
Inland lakes of Oregon			885,000					885,000
Inland lakes of Washington			385,000					385,000
Nebraska waters								400,000
Potomac River								5,150,000
Total	62,070,000	20,912,000	81,135,000	90,178,000	48,702,000	45,467,000	49,637,000	732,426,000

* Includes Detroit River.

Prof. Rasch, of the Norwegian University of Christiania, has made a very successful and, at the same time, suggestive experiment in the method of propagating salt-water species. Finding a deep natural lagoon that extended about a mile inland from the sea, narrowing at the end to the width of a large trench, a basin was formed, covering some 300 acres, with a mean depth of 40 feet, into which the waters emptied. A fence was constructed across the lagoon, which, while it did not interfere with the ebb and flow of the tide, prevented the outward passage of fish. Within the inclosure the hatching apparatus was erected for salmon and sea-trout spawn, having connection with two small fresh-water lakes supplied by springs. The fry in the ponds are for a time fed on fine-chopped mussels and then permitted to go into the salt-water basin. Thus they become "acclimated," so to speak.

A like experiment might be tried with our fresh-water fish. The matter should come before our State commissioners and the National Government. Suitable places could readily be found. The work might prove costly, but unquestionably the results would evince the expediency and wisdom of the attempt. Ponds and grounds in close proximity to the Great Lakes—and indeed a part of them, as in the instance above cited—with a hatchery within the inclosure, would procure for the fry the most natural and therefore the best accommodation and preparation for a larger and stronger life. The plans might take in such extensive cribbing as lake commerce demands, where the "breakwater" and storm harbor are necessities. If 10,000,000 fry could be placed in such confinement till they were from 2 to 5 inches long, and at the proper time permitted to escape into the larger body of water, it would not be death to them, for "what seems so is transition." They would find no change in element or provender, and our lake fisheries would soon begin reaping the rich reward of an experiment in pisciculture that must of necessity yet lead to a wider field in the domain under our consideration to-day.

24.—METHODS EMPLOYED AT CRAIG BROOK STATION IN REARING YOUNG SALMONOID FISHES.

BY CHARLES G. ATKINS,
Superintendent U. S. Fish Commission Station at Craig Brook, Maine.

The station of the U. S. Fish Commission at Craig Brook was founded in 1889, on the same site where, in 1871, the first attempt at the artificial spawning of salmon in the United States was made. This site had been selected by the commissioners of fisheries of the States of Maine, Massachusetts, and Connecticut for that experiment because of its proximity to the salmon fisheries of the Penobscot River and the facilities presented for the maturing of the spawn that might be obtained The collection of spawn has been carried on in the vicinity annually from 1871 to the present time, with the exception of the three years 1876, 1877, and 1878, and since 1879 the development of the spawn has been conducted constantly at Craig Brook. No attempt was, however, made to rear the fry of any species until 1886. Two years later it was definitely determined to found a permanent station at Craig Brook, and in 1889 the purchase of the grounds was effected and permanent improvements begun.

The station is located in the town of Orland, Me., 7 miles east of Bucksport, a seaport on the Penobscot River. Its territory embraces a tract of land extending between Allamoosook Lake and Craig Pond and embracing within its limits the entire length of Craig Brook, which connects those two bodies of water. Its latitude is about 44° 42′ N. The mean annual temperature and precipitation are believed to approximate those of Orono, 25 miles distant, namely, 42·48° F. [5·8° C.] and 45·44 inches [116 cm.]. The range of air temperature observed at the station is from 18° F. below zero to 92·5° F. above [—27·7° C. to 33·6° C.]. Frosts not infrequently occur as late as the 1st of June and as early in autumn as the first week in September. The lakes in the vicinity are commonly covered with ice before the end of November, and they are not often released until near the end of April.

The water supply is derived from Craig Brook and from three large and several lesser springs. The source of the brook is Craig Pond, which affords a constant supply of exceedingly transparent water, warm in summer and cold in winter, moderated, however, in both extremes by the water from the springs, which mingles with the brook in its lower course, forming about a third of its volume. It is this mixed water which is mainly used in the rearing of fish. Its temperature ranges from 34° F. [1·1° C.] to 70° F. [21·1° C.]. The lowest monthly mean in 1893 was 35·8° F. [2·1° C.] in February. The highest was 64·6° F. [18·1° C.] in August. The total volume is variable, ranging from 875 to 3,000 gallons and averaging about 1,200 gallons per minute. The difference of level between the source and mouth of the brook is about 190 feet. The sharpest descent is just above the hatchery and rearing troughs, which therefore receive well-aërated water. The conformation of the ground offers good facilities for the distribution and utilization of the water.

The leading motive in the foundation of this station was the desire to apply to the Atlantic salmon the system of rearing fish to the age of at least several months before liberating them. This motive has determined not only the principal subjects of the work, but also to a considerable extent the fixtures and methods. The scheme of work was determined in outline several years before the acquisition of full title to the premises, and, circumstances rendering it desirable to enter at once on its development, it became necessary to have recourse to movable apparatus, pending authority for permanent improvements. Hence the erection of a series of small troughs in the open air, which gave such excellent satisfaction that enlargement took the same direction; and it has thus come about that the rearing operations of the station down to the present time have been almost exclusively conducted in open-air troughs. A series of ponds has been constructed, but with the exception of a few small ones none of them have been as yet brought into use.

The troughs are for the most part such as are used in the hatchery for the maturing of spawn, and their form and size have been adapted to the hatching apparatus which has been in use at the Maine station for many years. The eggs are developed on wire-cloth trays measuring 12½ inches in width and length, and the troughs are therefore 12¾ inches wide. Their depth is 9 inches and their length is 10 feet 6 inches. Such short troughs were adopted for two reasons: (1) It was thought that a greater length might involve the exposure of the eggs near the lower end to the danger of a partial exhaustion of the air from the water by the eggs above them; (2) these short troughs are very convenient to cleanse and to move about for repairs or other purposes. They are made of pine boards seven-eighths inch thick. On the inside they are planed and varnished with asphaltum. When used for rearing fish each trough is fitted with a pair of thin wooden covers reaching its entire length, hinged to the sides and meeting each other, when closed, at a right angle, forming, as it were, a roof over the trough. When closed they protect from predatory birds and other vermin; when open they are fixed in an upright position, in effect adding to the height of the sides and preventing the fish jumping out. The time spent in opening and closing the troughs is by this arrangement reduced to a minimum.

Water is fed through wooden tubes, and the volume admitted is regulated by slides. The exit of the water is through another tube or hollow plug standing upright near the lower end of the trough, and by its height governing the depth of the water. The outlet tube is movable and is taken out in cleaning. A wire-cloth screen just above the outlet tube prevents the fish escaping.

In a trough of standard size 2,000 fry are generally placed, and to accommodate the large numbers of fish reared we bring into use sometimes nearly 200 troughs, which are of necessity placed in the open air. They are arranged in pairs with their heads against the feed troughs, supported by wooden horses at a convenient height from the ground. They are given an inclination of about 2 inches to facilitate cleaning.

The volume of water fed to each trough has varied from time to time, but is ordinarily about 5 gallons per minute, which renews the water every four minutes. The ordinary arrangement is to use the water but once in the troughs, letting it waste into some small ponds in which yearling and older fish are kept; but there is one system of 52 troughs arranged in four series, which use in succession the same water. From these we have learned that young salmon thrive quite as well in the fourth series as in the first. Indeed, by an actual test, with fish of like origin and character in each series, the fish reared in the fourth series were found to grow faster, to an important degree, than those in the first. This phenomenon probably resulted from a somewhat higher temperature which the water acquired in passing through the several series. A like observation has been made on a few salmon maintained for a few weeks in the warmer water of a neighboring brook.

As already stated, the activity of the station has been mainly occupied with Atlantic salmon, but there have been reared each year a few landlocked salmon and brook trout, and occasional lots of other salmonoids, such as Loch Leven, Von Behr, Swiss-lake, rainbow, and Scotch sea trout. All these have received the same treatment. With the exception of the rainbow trout, they are all autumn-spawning fishes, and their eggs hatch early in the spring.

The embryos of salmon begin to burst the shell in the month of March, and the 1st of April may be stated as the mean date of hatching. If the open-air troughs are in order—and we aim to have them so—the eggs are counted out into lots of 2,000 or 4,000 each and placed before hatching in their summer quarters. The water is at that time very cold, the development of the alevins is slow, and it is not until the latter part of May that the yolk sack is fully absorbed. June 1 is, therefore, the date when feeding is ordinarily begun. The growth of the fish is at first slow, the water being still cool, but is accelerated as the summer passes away. In October and November, beginning commonly about the middle of October, most of the fish are counted out and liberated, but a small number, rarely more than 15,000, being carried through the winter at the station.

The reserved fish are sometimes left until midwinter in their summer quarters, and with a careful covering of the conduits and banking of the troughs themselves with coarse hay and evergreen boughs it is possible to keep them there the year round; but for ordinary winter storage there is provided a system of sunken tanks covered by a rough shed with a constant water supply. These tanks are molasses hogsheads, securely hooped with iron, sunk nearly their entire depth into the ground, each with an independent water supply and waste, the perforation for the latter being near the surface. They have a capacity of from 100 gallons of water upward, and will carry safely each 500 to 700 fish in their first winter, that is, just approaching the age of one year. This arrangement has answered its purpose fairly well, and in a very rigorous climate or where the water is very cold it is to be recommended; but since its construction it has been discovered that at Craig Brook it is not at all difficult to protect the ordinary troughs in such a way as to insure their safety from freezing, and their attendance through the winter is less troublesome than that of the sunken tanks.

A list of the articles employed for food at the station since its foundation, if designed to include those used on an experimental as well as a practical scale, would be a long one, and I will content myself with naming the following: On a practical scale we have used butcher's offal, flesh of horses and other domestic animals by the carcass, fresh fish, maggots; and on an experimental scale, pickled fish, fresh-water mussels, mosquito larvæ, miscellaneous aquatic animals of minute size. In the production of maggots we have also made use of large quantities of stale meat from the markets and some barrels of fish pomace, in addition to the articles mentioned above.

The butcher's offal comprises the livers, hearts and lights of such animals as are slaughtered in Orland and Bucksport—mainly lambs and veals. These are collected from the slaughter-houses twice or thrice weekly, and preserved in refrigerators until used. The quantity of such material to be had in the vicinity has been inadequate to our needs and we have been compelled to look in other directions for food.

The flesh of horses has been used only during the season of 1893. Old and worn-out horses and those hopelessly crippled or dying suddenly have been bought when offered, and used in the same way as the butcher's offal; the parts that could be chopped readily have been fed direct to the fish so far as needed, and other parts have been used in the rearing of maggots. The season's experience has been so satisfactory that greater use will be made of horse flesh hereafter.

Next to the chopped meat, maggots have constituted the most important article of food, and their systematic production has received much attention. A rough wooden building has been erected for the accommodation of this branch of the work, and one man is constantly employed about it during the summer and early autumn months. The maggots thus far employed are exclusively flesh-eaters, mainly those of two undetermined species of flies—the first and most important being a small, smooth, shining green or bluish-green fly occurring at the beginning of summer and remaining in somewhat diminished numbers until October, and the other a large, rough, steel-blue fly that makes its appearance later and in autumn becomes the predominating species, having such hardiness as to continue the reproduction of its kind long after the occurrence of frosts sufficiently severe to freeze the ground.

In outline the procedure is to expose the flesh of animals in a sheltered location during the day, and when well stocked with the spawn of the flies to place it in boxes which are set away in the "fly house" to develop; when fully grown the maggots are taken out and fed at once to the fish. The materials used for the enticing of the flies and the nourishment of the maggots have been various. Stale meat from the markets has been perhaps the leading article, but we have also used such parts of the butcher's offal and of the horse carcasses as were not well adapted to chopping; fish, fresh, dried or pickled; fish pomace from herring-oil works, and any animal refuse that came to hand. Fresh or slightly tainted meat has been used to greater extent than any other material, and has proved itself equally good with any. Fresh fish is very attractive to the flies, and when in just the proper condition may be equally good with fresh meat, but some kinds of fish are too oily, for instance, alewives and herring, and all sorts thus far tried are apt to be too watery. A very limited trial of fish dried without salt or smoke indicates that it is, when free from oil, a very superior article; it has, of course, to be moistened before using. Its preparation presents some difficulties, but in winter it is easily effected by impaling the whole fish on sticks and hanging them up, (after the manner of alewives or herring in a smokehouse) under a roof where they will be protected from rain without hindering the circulation of air; in this way we have dried many flounders and other refuse fish from the smelt fisheries, which are conducted with bag nets in the vicinity of Bucksport. Doubtless a centrifugal drying machine might be successfully used for this purpose in summer. Pickled alewives, freshened out in water, have been found to answer fairly well, when other materials are lacking, at least to give growth to maggots otherwise started. Fish pomace has not thus far given satisfaction, but seems worthy of further trial.

It is commonly necessary to expose meat but a single day to obtain sufficient fly spawn; the larvæ are hatched and active the next day, except in cool weather, and they attain their full growth in two or three days. To separate them from the remnants of food and other débris was at first a troublesome task. It is now effected as follows: the meat bearing the fly spawn is placed on a layer of loose hay or straw in a box which has a wire-cloth bottom, and which stands inside a slightly larger box with a tight wooden bottom. When full grown the maggots work their way down through the hay into the lower box, where they are found nearly free from dirt. When young salmon or trout first begin to feed they are quite unable to swallow full-grown maggots. Small ones are obtained for them by putting a large quantity of fly spawn with a small quantity of meat, the result being that the maggots soon begin to crowd each other and the surplus is worked off into the lower box before attaining great size. No attempt is, however, made to induce the young fish to swallow even the smallest maggots until they have been fed a while on chopped liver.

In the above methods maggots are produced and used in considerable numbers, sometimes as many as a bushel in a day. Through September, 1893, although the weather and some other circumstances were not very favorable, the average daily production was a little over half a bushel. They are eagerly eaten by the fish, which appear to thrive on them better than on dead meat. Having great tenacity of life, if not snapped up immediately by the fish they remain alive for a day or two, and, as they wriggle about on the bottom, are almost certain to be finally eaten; whereas the particles of dead flesh that fall to the bottom are largely neglected by the fish and begin to putrefy in a few hours. In the fish troughs there are, therefore, certain gains in both cleanliness and economy from the use of maggots which may be set down as compensating the waste and filthiness of the fly-house.

As the growth of maggots can be controlled by regulation of the temperature, it is possible to keep them all winter in a pit or cellar, and advantage is taken of this to use them during winter as food for fish confined in deep tanks not easily cleaned.

The offensive odors of decaying flesh may be largely overcome by covering it, on putting it away in the boxes, after the visits of the flies, with pulverized earth, and it is not improbable that by this or some other method the business may be made almost wholly inoffensive, but in its present stage of development it is too malodorous to admit of practice in any place where there are human habitations or resorts within half a mile of the spot where the maggots are grown.

As remarked above, only flesh-eating maggots have yet been tried. It would be well worth while to experiment with the larvæ of other species, such as the house fly, the stable fly, etc. There is also a white maggot known to grow in heaps of seaweed. Should the rate of growth of either of these species be found to be satisfactory they might be substituted for the flesh maggots with advantage.

Occasional use has been made of fresh fish for direct feeding. When thrown into the water after chopping it breaks up into fibers to such an extent that it is not very satisfactory, and I do not suppose we shall use it in the future, unless in a coarsely chopped form for the food of large fish. A few barrels of salted alewives have been used, and if well soaked out and chopped they are readily eaten by the larger fish and can be fed to fry, but are less satisfactory with the latter, and like fresh fish they break up to such an extent that they are only to be regarded as one of the last resorts.

Fresh-water mussels have been occasionally gathered in the lake close to the station when there has been a scarcity of food. Those employed belong almost wholly to a species of *Unio*, which abounds over a considerable area of soft bottom, under a depth of 2 to 10 feet of water. Many were taken with a boat dredge; more were scooped up with long-handled dip nets of special construction. Finally a wide, flat dredge was made, to be drawn by a windlass on the shore and manipulated by means of poles from a large boat. When needed for food the mussels were opened with knives—a great task—and chopped. The meat is readily eaten by all fishes, and appears to form an excellent diet. Being more buoyant than any other article tried, it sinks slower in the water and gives the fish more time to seize it before it reaches the bottom, a consideration of considerable practical importance. The labor involved in dredging and shelling is a serious drawback, but were the colonies of unios sufficiently extensive or their reproduction rapid enough to warrant expenditure of time in experimentation, improved methods might be devised, which would put this food-source on a practicable basis.

During the seasons of 1886 and 1888 some use was made of mosquito larvæ. Near the station is an extensive swamp where these insects breed in great numbers. From the pools of water the larvæ were daily collected by means of a set of strainers specially devised for this use. Barrels filled with water were also disposed in convenient places near the rearing troughs, and were soon swarming with larvæ from the eggs deposited by the mosquitoes on the surface of the water. When near the completion of their growth, which was only some ten days after the deposit of the eggs, the larvæ (or pupæ) were strained out and fed to the fish. No kind of food has been used at this station that has been more eagerly devoured, and so far as our observation has gone no other food has contributed more to the growth of the fish; indeed, I am inclined to put them at the head in both respects. It was found, however, that the time expended in collecting them was out of all proportion to the quantity of food secured, and pending opportunity for further experiment their use was discontinued. I think it quite possible that an arrangement might be devised whereby the greater part of the labor might be saved. Perhaps a series of breeding tanks arranged in proximity to the fish troughs, into which the water containing the larvæ might be drawn when desirable by the simple opening of faucet, would solve the problem.

Various methods of serving the food have been tried, but at present everything is given with a spoon. The attendant carries the food with the left hand—in a 2-quart dipper if chopped meat, in a larger vessel if maggots—and, dipping it out with a large spoon, strews it the whole length of the trough, being careful to put the greater portion at the head, where the fish nearly always congregate. Finely chopped food, for very young fish, is slightly thinned with water before feeding. At one time the finest food was fed through perforations in the bottom of a tin dish; the food was placed in the dish, which was dipped into the water a little and shaken till enough of the food had dropped out of the perforations; this practice was laid aside because it was thought that the food was too much diluted. In feeding maggots it was, at first, the practice to place them on small "feeding boards" of special construction suspended over the water in the troughs and let them crawl off into the water; but whatever advantage this method may have had in furnishing the meal to the fish slowly was more than counterbalanced by the extra labor of caring for the boards and by the offensive odor, and it was abandoned. For use in feeding fish in a pond a box containing a series of shelves, adown which the maggots slowly crawl, was found sufficiently useful to be retained.

It is the common practice to feed all meat raw except the lights, which chop better if boiled first, except also occasional lots of meat that are on the point of becoming tainted and are boiled to save them. All meats fed direct to the fish are first passed through a chopping machine. The machine known as the "Enterprise" is the one now in use. It forces the meat through perforated steel plates. The plate used for the smaller fish has perforations $\frac{3}{32}$ inch in diameter, and for coarser work there are two plates $\frac{3}{16}$ inch and $\frac{3}{8}$ inch, respectively. It is operated by a crank turned by hand. Food is given to those fish just beginning to eat four times a day (in some cases even six times). As the season progresses the number of rations is gradually reduced to two daily. In winter such fish as are carried through are fed but once a day.

The cleaning of the troughs has been a troublesome matter, and the subject of much study and experiment, but nothing more satisfactory has been found than the following practice: The troughs are all to be cleaned daily—not all at one time, but as time is found for it in the intervals of other work. To facilitate cleaning, the troughs are inclined about 2 inches. The outlet is commanded, as already explained, by a hollow plug. When this is drawn the water rushes out rapidly and carries most of the débris against the screen. The fishes are excited, and, scurrying about, they loosen nearly all dirt from the bottom; what will not otherwise yield must be started with a brush, but after the first few weeks the brush has rarely to be used except to rub the débris through the outlet screen. Owing to the inclination of the trough the water recedes from the upper end until the fishes lying there are almost wholly out of water, but, although they are left in that position sometimes for 10 or 15 minutes, no harm has ever been known to result.

It has been the common rule at the station to count all the embryos devoted to the process of rearing, either before or after hatching; to keep an accurate record of losses during the season, and to check the record by a recount in the fall. When eggs are counted they are lifted in a teaspoon.

The counting of small fish is effected in this way: The fish are first gathered in a fine, soft bag-net, commonly one made of cheese-cloth, and from this, hanging meanwhile in the water, yet so that the fish cannot escape, they are dipped out a few at a time, in a small dipper or cup, counted, and placed in a pail of water or some other receptacle. This counting is generally preliminary to weighing, and in this case the fish, after counting, are placed in another bag-net, in which they are lowered, several hundred at a time, into a pail of water which has been previously weighed, and the increase noted. With care to avoid transferring to the weighing pail any surplus water, this is a correct method and very easy and safe for the fish.

In conclusion, I submit some estimates of cost. In September, 1893, we fed fry that were estimated at the close of the month to number 238,300. There were also a few hundred larger fish. From the known total outlay for food, attendance, and superintendence a suitable allowance is made for the maintenance of the older fish, and the balance is charged to the fry. By this method we arrive at the following results:

Cost.	Total.	Per fish.
Food	$155.00	$0.00065
Attendance	99.79	.00042
Superintendence	205.96	.00086
Total	460.75	0.00193

Applied to the rearing operations of 1891, a similar calculation gives us this result: The fry that were carried through the season from June to October, inclusive, cost, for food, attendance, and superintendence, $0.0081 each; that is, about four-fifths of a cent each for the term of five months.

25.—THE PROPAGATION OF BLACK BASS IN PONDS.

BY WILLIAM F. PAGE,
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About 1852 several gentlemen at private expense introduced the black bass into the Potomac River by transferring the adult fish from Wheeling Creek, West Virginia. The wonderful multiplication and dissemination of these fish throughout the entire Potomac basin attracted the attention of the various State fish commissions which were created in the seventies, and in many States the effort was made to add to the fish supply by broadening the habitat of the black bass. But while fish-culturists were everywhere striving to perfect the methods and apparatus employed with the salmonidæ and shad, nowhere was any systematic effort being made toward the propagation of the bass by artificial methods. Several reasons obtained for the apparent neglect of this prince of fishes, among which may be mentioned the meagerness of the appropriations for propagation; the fact that nearly all States, as well as the United States, engaged in fish-culture were annually, at the period of the bass spawning, devoting every energy toward the multiplication of the shad; and, above all, the fact that the eggs of the black bass belonged to the class commonly called glutinous, a class until recently considered impossible of treatment by artificial methods of impregnation and incubation.

In the light of late achievements in this direction, notably in the impregnation and freeing of the eggs of the wall-eyed pike by Prof. Jacob E. Reighard, and the successful hatching of the glutinous eggs of the white and yellow perch at the Central Station of the U. S. Commission of Fish and Fisheries, it is pertinent to ask if it was not a hasty judgment which placed the artificial propagation of the black bass beyond the pale of the possibilities. If I dared to express an opinion on this subject it would be that a part of the effort which has been expended on fishes of less value would place the secret in our hands. However, within the past decade the bass, by the demands of its ardent friends, the anglers of the United States, has commenced to attract and hold the attention of fish commissioners and fish-culturists. The U. S. Commission of Fish and Fisheries has for several years been engaged in collecting the adult fish from the overflow districts of Illinois and distributing them into new and depleted waters, on the same plan, though on a larger scale, which proved so successful in stocking the Potomac River. Not only this, but at the Neosho Station an effort was inaugurated, not without success, in 1889, to propagate the young in ponds. The fish commissioners of the State of Missouri have also been engaged for some time in the propagation of the black bass in ponds at Forest Park, in St. Louis. In the fourteenth report of the Wisconsin Fish Commission an earnest plea is presented for the construction of a system of ponds to be devoted to bass culture.

The following remarks on the propagation of black bass in ponds are based upon extracts from Dr. Henshall's "Book of the Black Bass," reports of the Missouri, Wisconsin, and Virginia Fish Commissions, newspaper articles, and the "log book" of the Neosho Station, embracing a period of four years. Recognizing the probability of the inaccuracy of a part of the data and conclusions, free criticism is invited.

In the first place, it should be understood that reference is had to the large-mouthed black bass (*Micropterus salmoides*) which nature has the better adapted to raising in ponds; and, in the second place, the object is to obtain a large number of young fish for stocking purposes, not a limited number of large fish for angling. When we come to consider the question of food for the bass under domestication the importance of this latter point will be recognized.

Spawning period.—Dr. Henshall says:

> The period of spawning extends from early spring to midsummer, according to the section of country and temperature of water; * * * in the Southern States occurring as early as March, and in the Northern States and Canada from the middle of May until the middle of July, always earlier in very shallow waters and somewhat later in those of greater depth.

This can be accepted as a safe guide, for in the main it is undoubtedly correct, though instances have come under my observation which would suggest a modification of the periods. In January, 1893, I saw the bass on their nests in San Marcos Spring at San Marcos, Texas, and in Olmos Creek at San Antonio, Texas. The questions which then presented themselves to me were, "Are these sporadic cases?" or "Do the bass in Texas produce more than one crop a year?" It should be understood that these waters (particularly the San Marcos Spring) are generous warm springs, never freezing, and at the time of which I speak the *Caladium esculentum* was luxuriating on the margin and the *Nelubium lutem* growing in mid-stream in full bud, ready to flower. From my knowledge of other fishes, close allies to the bass, I am of the opinion that under the conditions just described the generative organs of the bass do not wait upon the seasons, for under such conditions it is always summer.

Nest-making material.—However this may be, the fish-culturist having the bass under care will receive ample warning of their intended spawning. A few days in advance the fish pair off and select a place for their nest. The selection of the location as to depth of water, material for nest, environment, etc., seem in a large measure to be matters of individual choice. I have known bass to decline a nice lot of clean gravel, in water 3 feet deep and 8 feet away from the embankment of the pond, to build a nest on the naked clay bottom, within hand reach of the bank on which visitors were passing almost every hour. My experience is that a majority of the bass prefer a nest of clean gravel in water about 30 inches deep. But no matter how dirty the gravel may be, or how overgrown with moss and algæ, when the bass need it they will clean it as bright as if every particle had been polished with a brush. It is a fact worthy of comment that the nest-building on the part of the bass does not wear so hard upon their fins as in the case of the trout. In the ponds at Neosho are bass which we know to have built at least three series of nests. (As they were adult fish when captured from the Illinois River, they may have built more.) Not one of these bass shows the least fraying of the caudal fin. On the contrary, I have known trout, after one season's work, to seriously impair the caudal and anal fins. The nests are generally circular, though oftentimes irregular in shape, slightly depressed toward the center. In size they vary from 18 inches to 3 feet in diameter. Dr. Henshall says: "The diameter of the nest is usually twice the length of the fish."

Nest guarding—As before intimated, the eggs are viscid and attach themselves as soon as voided and impregnated to the floor of the nest. Then commences a parental devotion worthy of imitation on the part of some higher animals. For a time I was under the impression that the female deserted the nest and the male fish took charge. From closer and more extended observation I am now of the opinion that the female is in direct charge, whilst the male acts as an outer sentinel, patrolling 8 or 10 feet away. There is nothing smaller than a man that a bass won't attack when on duty guarding a nest, and there is nothing smaller than a man who attacks a bass at this time. It might be well here to remark that because the nest is bright it makes the female a shining mark for the natural enemies of the bass. On one occasion I saw a fishhawk dart down and take a female from over her nest. The fish-culturist can lessen the probabilities of such disasters by planting a variety of water lilies in the spawning pond, under the broad leaves of which the bass may seek shelter when in danger.

Hatching—The eggs usually hatch in from 8 to 10 days (9 days is the average at Neosho), though undoubtedly the period of incubation, as with all other fish eggs, is dependent upon temperature. Prior to the hatching of the eggs the female stands guard directly over the nest, maintaining a gentle motion of the fins for the purpose, it is thought, of providing a change of water over the eggs. When the fry leave the eggs the tactics of the mother fish are changed. She no longer stands guard over the nest, but circles around the school, whipping back truants and driving off intruders.

Size and appearance of the fry.—In the Missouri Fish Commission report (fourth) it is stated that the young bass when first hatched are of minute size. The Wisconsin report (fourteenth) says they are transparent and so small as to be invisible to the naked eye. Dr. Henshall says:

> When hatched, the young bass are almost perfectly formed, from one-fourth to one-half inch in length, and cover the entire bed, where they can be easily detected by their constant motion.

The bass which have been under my care do not fill either of these descriptions. They do not average over one-fourth inch in length and are colorless for the first three to five days. At the end of that time they are schooling well and pigment forms along the back, making them appear quite dark when viewed from above looking downward; though when caught upon a fine net of bolting cloth or cheese cloth the color in an individual fish is hard to distinguish.

The school.—It is not easy to determine any definite time or age at which the school disperses. I have found individual members of a school, scarcely half an inch long, widely separated in a pond; and again, have removed an entire school of perfectly formed bass over an inch in length. The breaking up and dispersal of the school would seem to depend partly upon the scarcity or abundance of food, the continued watchfulness or neglect of the parent, and possibly to some extent upon the degree of venturesomeness animating a particular school. When the school has dispersed the young seek the minute crustacea, larvæ, and insects in the shallow water. The Wisconsin report asserts that the female locates the young in the shallow waters, but I am inclined to think that it is not a matter of parental direction but of instinct which guides the young bass to the source of greatest safety and food supply.

Necessity for the work.—It may be asked, if bass are such excellent parents and accomplish the high rate of impregnation which some writers ascribe to them, where is the necessity of putting more than a few adults in a pond, letting them alone, and later harvesting a crop of young? To such a question I would answer that after the dispersal of the school, unless food of an acceptable kind be present in abundance, an adult bass does not stop to examine the birth-marks of a straggling youngster who may cross his path. There can be no question but that the largest part of the young so zealously guarded early in the season later furnish food for some adult bass, possibly its own progenitor. Again, the bass are like the trout in that every school furnishes its examples of giants, which make short work of their weaker brethren. In the autumn sorting of the spring crop, left undisturbed through the summer in the nursery pond, three and sometimes four sizes of young bass will be found, the largest of which show by their very size they have been guilty of fratricide.

Propagating ponds.—The Missouri Fish Commission, in their report for 1885–86, recommend for ordinary pond culture stocking on the basis of three males and three females per acre. In their propagating ponds in Forest Park they formerly used 75 breeders for a lake of 3½ acres, though last year they employed 100 males and 100 females for the same lake. So far as I have been able to determine, Mr. W. C. Germain, an employé of the Missouri Fish Commission, was the first to copy from the German carp-culturists the method of transferring young bass to nursery ponds. Mr. Charles Wilmot, superintendent of fish-culture for the Dominion of Canada, recommends the opposite course of removing the breeders after the nests are hatched out. This latter method is open to objection in that it is difficult to capture the breeders without injury either to them or their young.

Spawning pond.—With my present information I recommend the following course: Let the spawning pond be built so that at least one-fourth of it will have a depth ranging from feather edge to 1 foot deep. In this portion of the pond plant *Potamogeton* to facilitate the propagation of crustacea to furnish food for the young bass which will escape the net in the process of transferring from the spawning pond to the rearing pond. The remainder of the pond should have a gradually sloping bottom, and consequent increase of depth, to the kettle (or draw off), where the water should be at least 3 feet deep for the warm Southern States and 12 to 14 feet deep for the Northern States or Canada. In the middle third of the pond plant lilies, preferably those having the largest pads. These will not only furnish the breeding fish with a place to hide from the fishhawks, but also serve as sunshades during the summer.

Preparation and management of spawning pond.—Clean gravel ranging from the smallest shot to hazelnut size should be provided in the pond. The disposition of this gravel is a matter of some importance. I prefer it put in water from 18 inches to 3 feet deep and near the pond bank. As before stated, the fish will not always use the gravel, but the majority will. By putting the gravel near banks, and so inducing the fish to make their nests there, the entire process of spawning and incubation is under easier observation, and labor and time are saved in transferring the young. Moreover, if it is desirable to remove a nest 10 feet or more from the bank it can be done only by wading into the pond. This is not only awkward work but it disturbs the other fish at a time when nature is demanding the greatest degree of quiet. Put the gravel about 5 or 6 feet from the banks in a number of small heaps. When the bass commence nest-building the attendant will do well to keep the pond and its contents under constant surveillance. Maintain a close watch for fishhawks and herons; but frogs, snakes, and turtles getting into the pond just now need occasion no immediate alarm. A few years since I disturbed a snake, which, running into the pond, crossed the dead-line of a bass nest. Quick as a flash the bass had his snakeship by the middle and was shaking him as a terrier does a rat. Observe and record, as near as may be, the date each lot of eggs is laid, and so know the better when to expect the young to hatch.

The nets.—Before the fry leave the eggs be prepared with a net of cheese cloth to use in collecting them for transferring to the nursery pond. Two nets will be found serviceable for this purpose. The main net should be about 30 inches square, supported by ribs from above. To the center of the ribs arrangement should be made for attaching a handle when the net is to be used 5 or 6 feet from the shore. The net should sag to an open pocket in the center, which can be closed and tied with a draw string. Messrs. A. B. Shipley & Son, of 503 Commerce street, Philadelphia, Pa., advertise a folding minnow net which answers admirably, except that the mesh they furnish is too coarse and needs to be replaced with a yard of closely-woven cheese cloth. The secondary net is easily made from an ordinary landing net by replacing the netting with cheese cloth. This will be found of service in finishing up the remnants of schools which escape the larger net.

When to net.—After the hatching is completed and the young, under the guidance of the parent fish, are schooling, commence to net them out into tubs filled with water from the pond. Do not make the mistake of filling the tubs with any other water than that from the spawning pond—not because this water has any virtue in itself, but because by using it you avoid the risk of change of temperature. I have yet to handle an embryo fish more sensitive to change of temperature than the bass.

How to net.—The process of netting, to be thorough, requires patience and that degree of skill which comes only with practice. When possible stand on the bank, introduce the net with a gentle, scarcely perceptible side movement under the school of bass, and cautiously lift it out. As soon as the net has cleared the water, with a quick turn bring it over the tub so that that part of the net holding water and fish comes into the water in the tub. An assistant standing near the tub, by catching the sides of the net, helps in the accuracy of the latter part of this operation. The operator continues to hold the rod to which the frame of the net is attached; the assistant slips his hands into the tub and unties the draw string of the net pocket. The net is then gently lifted out of the tub. Alongside of the tub should be a pail of pond water and a dipper. As the operator lifts out the net the assistant should wash off such fish as may stick to the cheese cloth with water from the pail. For this purpose never use anything but water. By no means resort to a feather or the equally bad practice of shaking the net. There is but one portion of the operation of collecting the young bass which requires celerity. It is the time when the net is being moved from the pond to the tub. All the remainder requires the utmost degree of painstaking care and time.

Transferring and planting.—The fish being in the tub, it remains to transfer them without loss of time to the nursery pond. It is, of course, a simple matter to take up the tub and walk the few steps intervening between the ponds, but the proper introduction of the young bass into the nursery pond is an operation requiring some degree of care, patience, and skill. In the first place the water supplying the two ponds should be from the same source, in which case it will be found that there is but slight difference in the temperature of the shallowest part of the nursery pond and the surface water of the spawning pond. However it may be, the water in the tub should slowly be brought to the temperature of that of the shallowest part of the nursery pond. It is here will be found the minute crustacea, daphnia, cyclops, and larvæ of the gnats on which the young bass are to forage; and it is here, in this shallow water, that they should be liberated. Not all dumped in at one spot, but slowly, carefully, gently ladled in—scattered all around the margin of the pond.

Construction of the nursery.—To attain the survival of the largest number of the young bass, the construction and management of the nursery pond demand their protection from enemies and the production of the greatest quantity of insect life suited to their sustenance. It will be found advantageous to have a number of small ponds rather than one large one. A good working-size will be a width not exceeding 12 or 15 feet, from 40 to 50 feet long, with a depth from 30 to 36 inches at the kettle. Where the lay of the ground is such as to permit, it is recommended to have the nurseries immediately adjoining and supplied by the same water as feeds the spawning pond. Such an arrangement simplifies the operation of transferring the young fish, and at the same time robs it of some of its dangers. As in all other ponds for fish propagation, the supply and discharge for each nursery pond should be independent of any other. They will be better when provided with bottoms sloping to the kettle. If the locality is infested with crawfish it is advised to pile or otherwise protect the banks. The entrance of snakes, frogs, and such enemies may be prevented by surrounding the pond with finely-woven screen, or, better yet, boards let into the earth a few inches and projecting 18 inches above the ground.

Amount and temperature of water for nursery.—The proper amount of water for the nursery is the minimum which will replace evaporation and seepage. In the early age of the bass any approach to a current must be strictly guarded against, for the young large-mouthed bass is not a strong fish or one loving a current. A current sweeping through the nursery pond would be about as desirable as a colony of snakes. Whilst these remarks are intended for the nursery pond they will apply to the spawning pond, especially at and for some time after the spawning period.

The young bass is able to stand any temperature to which the sun raises the water of the nursery. I have found the bass, just hatched, in water at 56° F., and two months later they were thriving with the temperature at 86° F. The first week in August, 1893, I found wild young bass in stagnant water at 98° F. Caution should be accepted here that bass grown in such very high temperatures are exceedingly tender and impossible of handling and transportation until the approach of fall and winter has gradually reduced the temperature and so hardened them. Moreover, under such conditions they are more liable to the attack of parasites, both external and internal. Whilst the bass has the ability to live in the extremes of 33° to 98° F., there are limits which, if they can be secured, will be found advantageous. M. Durand, of the National Society of Agriculture of France, states, as the result of his experiments, that the cyclops reproduces best at a temperature between 68° and 77° F., and that they can not resist higher than 95°. The young bass being so adaptable as to temperature, it is a safe conclusion that the best temperature for them is that at which their food best multiplies.

Stocking the nursery.—How many young bass shall be put into a pond? This very natural question is not easy to answer, for it depends upon the size of the pond and its capacity to produce food. With an unlimited quantity of food there would be little liability of overstocking. The secret how to produce natural food without limit is not yet in the possession of the mass of fish-culturists, and until this secret is common knowledge we must move with caution. If the nursery has been prepared in advance with the aquatic plants already suggested, some crustacea will be found to have taken up a home and commenced their reproduction. To a nursery in fair condition from 3,000 to 5,000 young bass may be allotted. The death of a part of these must be expected. However, should a large part of them by good fortune survive the first few weeks, they can later be divided into other nurseries.

Management of the nursery.—As the summer advances those fish which have commenced life with the highest degree of initial vitality will be noticed to be outstripping the less vigorous ones, and a closer observation will disclose that some of the larger ones are guilty of cannibalism. On the first signs of this—sooner would be better—the young bass should be collected and the sizes sorted into different ponds. It may be urged that when the work is conducted on a large scale this operation would require too much time and expense of labor. The answer is, neglect to do it and you will reap a diminished harvest of large fish. In my opinion the midsummer sorting of the young bass is of importance surpassed only by the necessity for removing the young from the spawning pond. The average length of six months' bass at Neosho is 3 inches, though I have frequently seen them of the same age measuring from 8 to 10 inches. Whoever has seen a bass choked to death by trying to swallow one of equal size will not doubt that the 8-inch fellow will diminish the number of the 3-inch fishes.

Food for the nursery.—So far I have been going on the supposition that no artificial food will be used, or any natural food supplied in addition to that which the pond will produce. It is evident that if even a fair per cent of the 3,000 or 5,000 fish in a nursery of the size recommended are to survive they must have more food than the pond can grow. For reasons already given, any addition of the smaller crustacea (except the *Gammarus*) can not yet be undertaken. At Neosho we resort to finely chopped beef-liver for the bass, and I am free to confess with not the most satisfactory results. At the Forest Park ponds of the Missouri Fish Commission a method is pursued which is not without advantages, but one which I am not prepared to unqualifiedly indorse. Several weeks before the bass spawn the attendant catches the little branch chub and puts them into the pond. The chub spawns and hatches out before the bass. When the young bass are transferred to the nursery they find a lot of young chub waiting to be eaten. One of my objections is that they also find a lot of old chub waiting to eat them. It is true that this objection could be obviated by hatching the chub artificially (as can easily be done) and turning only the young chub into the pond. To those who do not fear the risk of pampering to the natural cannibalistic propensity of the bass, this method will appeal by reason of its simplicity and cheapness; but this is something that I fear as much as any other factor yet encountered in the cultivation of the bass. My advice is, never feed your bass, old or young, on any kind of fish, unless it be crayfish; but start with the determination that they must be trained while under domestication to forego their natural inclination for fish diet. I am aware of the excellent work done with the bass at the Carp Pond, at Washington, D. C., in the summer 1892, when the ponds were infested with sunfish. But there are no means of determining what proportion of the young bass were devoured by the sunfish before they fell a victim to the parent bass.

Harvesting.—The harvesting should occur in the cool days of autumn, at which time the young bass with the greater ease and safety can be transported for distribution, and the ponds be allowed to remain bare during the winter to increase the quantity of insect life to serve as food for the next year's crop. Whatever necessity there is to avoid leaving any carp in the nursery or growing pond, the necessity is increased many fold in the case of the bass. The pond should be drawn very slowly, every opportunity allowed the fish to follow the receding water, and every circumstance avoided which would tend to frighten the fish into burrowing into the mud. Under fright the bass will burrow into the mud and live there an incredible length of time. Some three years ago we used a pond for bass one season, and when it was concluded to use it for shad the following season it was drawn off in the autumn to harvest the young and thoroughly rid it of bass. Unusual precaution was exercised to remove every fish. The pond was left empty for three weeks exposed to the frosts and winds of November, until the mud was dry and cross-checked. The pond was then filled, and in December 200 tons of ice were cut from it. To make assurance doubly sure the pond was again drawn in the following April and left empty for ten days. The young shad were introduced the first week in June. By the first of August it was noticed that other fish than shad were jumping for the flies in the dusk of early morning and evening. One hundred and fifty bass, averaging half a pound each, were captured from this pond, from which all the bass had been so carefully removed. There were no means within the limits of reasonable probability for 150 fish to have gotten into this pond, except by having burrowed in the mud and lived there several weeks while it was drying.

26.—FISH AND FISHING IN BRITISH GUIANA.

BY J. J. QUELCH, B. SC., C. M. Z. S.,
Curator in charge British Guiana Museum and Special Commissioner for British Guiana to the World's Columbian Exposition, Chicago, 1893.

The importance of the subject of fish and fishing in Guiana is one that can hardly be overestimated, and though the sea and rivers, and even the swamps, are stocked with palatable and delicious fish, yet thousands and thousands of salt fish are annually imported, and form, with plantains and such like fruit and vegetables, the staple diet of the poorer classes along the coast. There is no sufficient permanent supply of fresh fish in the local market, the people engaged in the fishing industry being either too few in number, or by no means constant in their catering to the wants of the community, though there is always a certain steady demand for their commodity.

The common food-fishes found in the markets include such forms as the snook (***Centropomus***), the gilbacker (***Platystoma***), the querriman and mullet (***Mugil***), the cuffum (***Megalops***), the bashaw (***Sciæna***), the jewfish (***Plectropoma***), the pacumah (***Batrachus***), and the flounder (***Platessa***), which are caught in the shallow water off the coast, or in the sheltered bays and mud-flats, and in the estuaries of the river even at some considerable distance from the sea. At certain times, especially during the long dry seasons, three species of fresh-water fishes are extraordinarily abundant. These are the "hassar" (***Callichthys***), and the "hoori" and "yarrow" (***Erythrinus***), which, on the drying up of the smaller creeks, are found in enormous quantities migrating across the savanna outlets to the larger streams, or inclosed in the small ponds, where often the hassars are densely buried in the soft mud. At such times groups of the village people will be found collecting along the creek beds, and bringing to the towns and villages barrels and boat loads of these fishes which have either been densely packed alive or have simply been thrown into some small vessels with but small quantities of water and a little grass for their protection from the sun.

Further inland these three species are equally abundant, but other much finer and larger fishes are obtainable and are largely used. Among such may be mentioned the haimura (***Macrodon***), the sunfish and lucanani (***Geophagus***), the pacu and morocot (***Myletes***), the perai (***Serrasalmo***), the cartaback (***Tetragonopterus***), biarra (***Hydrolycus***), the paruarima (***Hemiliopterus***), the daree (***Leporinus***), the tiger-fish (***Platystoma***), the lanlan (***Piratinga***), the arrowana (***Osteoglossum***), the arapaima (***Sudis***), and many others.

The daree, cartaback, and perai are small species, ranging from a foot to nearly 2 feet in length, though deep and thick in body; the haimura, tiger-fish, and paruarima are larger, reaching to from 3 to 5 feet, while the lanlan and arapaima are giants of their kind, and attain a length of from 12 to 15 feet respectively, the former being caught by long ground lines set at night, while the latter is shot by the Indians with their long harpoon arrows with separable barbs. The pacu are secured only in the higher parts of the rivers where they feed on the abundant water weeds (***Lacis***) growing on the rocks amid the rushing waters of the rapids and cataracts, at which times they are easily secured by the deadly flight of the Indian's arrow. The others are commonly secured by long lines or traps, constantly to be found along the rivers and creeks, and so arranged as to prevent the fishes caught from being devoured by other fishes and aquatic animals, such as alligators and others. The lines are set by means of long spring rods, which, when the fishes are caught, hoist them well above the surface and out of reach except to the fishing people who visit the lines at intervals and reset them with fresh bait.

The voracious and predaceous "perai" are so abundant in certain parts that they may be continuously caught by the mere dropping of the baited hook into the water, with a total disregard of the nature of the fleshy bait. Unless the hook be well secured by a stout wire, the fish generally, however, snaps himself free by a bite from the strong and sharp teeth, which, on account of their strength and sharpness, are made use of by the native Indians for cutting purposes in hunting, the jaw of this fish being always a part of the furnishing of the quiver in which the poisoned (oorali) arrows for the blowpipe are carried. These fishes are the great pests of certain parts of many of the great rivers, wounded and defenseless animals being often the victims or sufferers from their attacks—the armed stingray, even, generally showing a shortened tail and a much damaged fin expansion, owing to the bites from these water tyrants.

The lucanani and sunfish are almost equally abundant, and in certain places and at certain times of the year they can be caught by the mere cast of a fly, though the larger and heavier ones require much careful playing to secure them. These and many other common fishes readily take a fly and afford considerable sport to the angler.

There are easy methods in use by which the native people secure all varieties of fishes in almost unlimited quantity. The smaller fishes, like the daree, are easily secured by throwing pellets of the crushed leaves of the connami plant (*Clibadium asperum*) into the water. The fishes greedily devour the pellets, and being narcotized float helpless on the surface, and are rapidly picked up by the Indians ere the effect passes off, and are either used for bait for larger fishes or directly themselves for food.

On a much larger scale enormous quantities can be obtained by poisoning the water by means of the fish poison or "haiari." The haiari plants are cut into short pieces and pounded into pulp, and then mixed with water, so that the milky poisonous juice might the more readily be dissolved out. By casting this mixture into a stream or channel of the river that has been dammed up to prevent the rapid escape of the water, all the fishes in the immediate vicinity are affected and float after a time, according to their size, either quiescent or struggling on the surface. The larger kinds are rapidly killed or stunned by blows on the head and the desirable ones quickly secured. In this way hundreds of specimens of all sorts may be secured. It is a very effective but wasteful method, since it leads to the wholesale slaughter of large and small fish, the greater part of which is never secured.

When the larger fishes, such as the lucanani, the sunfish, the pacu, the tiger fish, the haimura, and others, are secured in very large quantities and of sufficient size, they are preserved for future use by the natives along the rivers by means of the method known as babracoting. This consists in smoking and drying the fish, as is done with other fish, on a wooden stage over the wood fire—the wooden stage being known as the "babracot." Fishes thus preserved can be kept with very little attention for long periods, and babracoted pacu and lucanini can often be obtained on the coast after a successful season in the interior. The common hassar, yarrow, and hoori are often thus cured by the negroes on the coast and kept for future use.

A species of *Myletes*, known as the "morocot," and very abundant in the rivers of the northwest district of Guiana, has recently become the subject of a small curing industry, and this might be extended, with enormous advantages, to other species. The lack of enterprise in the prosecution of such industries is certainly deplorable, though considering the ease with which the wants of the common people can be supplied under such favorable tropical conditions as exist in Guiana, it can hardly be remedied. When men, women, and children, with but a fish-hook and the commonest ground bait, can secure even from the canals and trenches in the town and the immediate neighborhood more than a sufficient supply of fish for their own requirements, the difficulty of the problem can hardly be removed.

To the ichthyologist a considerable degree of interest attaches to the subject of fish in Guiana, the more especially in that so little research has ever been prosecuted in this direction. Since the work of the Schomburgks, and the publication of the "Reisen in British Guiana," and the two volumes in the Magazine of Natural History series, no detailed attempt has been made to work up the subject, though various descriptions of fishes from Guiana have been published at different times. An interesting field for work here lies practically untouched. Hundreds of species that frequent the estuarine reaches, the canals and trenches, the sheltered and open savannah creeks, the distant forest streams, and the upper reaches of the rivers in the various parts of the country, are practically unknown, and yet await the description of the naturalist and the illustration of the artist.

Interesting as are the relations of distribution of the great groups—as, for instance, the extreme development in size and number, both as to species and individuals, of families such as the *Siluridæ* and *Characinidæ* as contrasted with paucity in others, as the *Cyprinidæ*, special interest is attached to many individual forms, of which the electric eel (*Gymnotus electricus*), the river stingray (*Trygon hystrix*), the barker and paruarima (*Hemiliopterus ornatus*), the four-eyes (*Anableps tetrophthalmus*), and the common hassar (*Callichthys littoralis*), may be mentioned.

The electric eels are common both in the higher and lower reaches of the rivers, and especially in certain parts of the estuary of the Essequibo, where they are frequently caught in the seine of the fisherman. The river rays too are common in the higher parts of the rivers, where extensive sand and mud flats abound, the colors of which they so much resemble as to be hardly distinguishable in the shallow waters. The wounds from the poison spines of these fishes are peculiarly dreaded by the river people, owing to the difficulty in healing the intense ulceration resulting from them.

The paruarima inhabits the upper reaches of the rivers and is remarkable for the peculiarly loud grunts or barks which it makes, and which evidently are intensified by the greatly disproportionate size of the head and thoracic portion. The peculiar division across the eyes of *Anableps* is too well known to require description; so marked is this development, however, that its common name, "four-eyes," would appear to be peculiarly appropriate. These fishes are met with in astonishing numbers all along the estuarine mud flats and creek mouths, and at low water especially will be found feeding along the courses of all the little mud rills over the exposed flats, from which they rush, on disturbance, with rustling noise to the water, where they can be seen cresting the surface in all directions—a great part of the head and even the body being exposed, projecting above the water, as they propel themselves vigorously forward with the tail and hinder part of the body.

The common hassar (*Callichthys littoralis*), the commonest of the Guiana fishes, is noteworthy in many respects. The enormous size and the peculiar arrangement of its scaly armor; the hardiness of its constitution, by means of which it can survive exposure for hours outside the water without damage, or exist buried in the soft mud during the dry weather, and its immense propulsive power, as shown in its migration from place to place on the savannahs during the progress of the dry weather, are full of interest. Its power of movement on the land, due to its great strength and to the peculiar size and structure of the anterior spine of its pectoral fins, by which it makes huge jumps and leaps, and generally manages to work itself back into the water if it be placed on the land, is a constant source of surprise to those who witness it for the first time. But the most curious feature in their life-history is to be found in their breeding habits. Unlike the generality of fishes, the hassars prepare a nest for their eggs, the structure being made up of leaves, straw, or grass, drawn or heaped together, in which the eggs are deposited, and the males then congregate in the vicinity of the nest, keeping guard as it were over the safety of the eggs.

Of the great coast monsters, the selachians, several species are known, though but little detailed observation has ever been made of them. Many species of the *Carcharias* and *Galeocerdo*, from 6 to 10 feet in length, frequent the shores, especially along the outsides of the wharves, where they are sometimes seen and are occasionally caught. Young specimens of these genera are frequently taken in the nets of the fishermen, and at times great damage is caused by the presence of those of larger growth. Further at sea the species of *Zygæna* are obtained, small specimens being met with on the mudflats. Great eagle rays, cow-nosed rays, and devil-fishes (*Ceratoptera*, *Rhinoptera*, *Aëtobatis*, etc.) occasionally are caught entangled in the nets, though more usually they drift into the rivers, among the wharves and shipping, and get entangled at the fall of the tide. So, too, with the species of *Pristis* (*P. pectinatus* and *perotteti*) which at times are obtained about 23 feet long, with a girth of over 10 feet. These are usually stranded by the fall of the tide on the flats, or in some narrow drainage trench along which they have traveled, unable to turn back.

As will have been gathered from the foregoing, native fish products play but little part in the trade of Guiana. Isinglass, or fish-glue, is exported in small quantities, this being the dried swim-bladder of the gilbacker fish, which is perhaps more plentifully taken than any other of the common food-fishes of the coast.

The chief fresh-water fishes, as already described, form the chief portion of the animal food of the native Indians, who, when no better can be obtained, boil up any of the smaller kinds, with an abundant supply of peppers, thus making a palatable and nutritious, but extremely hot, sauce, to be taken with the baked cassava or manioc cakes, which, to them, take the place of the "staff of life."

Parts of a few species are applied to industrial purposes by the Indians, of which the jaw of the perai, already mentioned, may be taken as an example. The finely-toothed palate bones of the arapaima (*Sudis gigas*) are highly prized by them, and are used as files to rub down and smooth off the bows made of the hard woods "washiba," "tibicuse," and "letterwood." The skins of a few species, such as the tiger fish (*Platystoma tigrinum*), are made into pouches, and the fish mentioned is usually selected by the peaiman, or "medicine man." By many of the savannah Indians, scraping implements or tattooing instruments are made of the anterior serrated spine of many of the siluroid fishes, the sharp edges being protected by a small bamboo case.

27.—FISH-CULTURAL INVESTIGATIONS AT ST. ANDREWS MARINE LABORATORY, SCOTLAND.

By W. C. McINTOSH, M. D., LL. D., F. R. S,
Member of the Fishery Board for Scotland, etc.

I.—ON THE FISHES DEVELOPED AT THE ST. ANDREWS MARINE LABORATORY (UNDER THE FISHERY BOARD FOR SCOTLAND).

Since 1883 special attention has been devoted at St. Andrews to the subject of the development of marine fishes, an attention which was first stimulated by the absence of reliable knowledge on this subject as well as of the eggs and life-histories of even the commonest and most important of our food-fishes. At this period the greatest uncertainty prevailed as to the floating or sinking of the eggs of such fishes; indeed, among strictly scientific men in Great Britain no attention had been given to the subject, and the most eminent of them thought that the floating or sinking of these eggs might be due wholly to the temperature of the water, just as others deemed it might be due to the oil-globule, overlooking the fact that many are devoid of that structure.

Previous to this period the life-history of scarcely a single marine food-fish had been studied in Great Britain. It was known that Sars had observed the development of the cod in Norwegian waters, and that Agassiz, Ryder, and others in the United States of America had paid considerable attention to those of their shores, but the field was almost untouched in this country. A commencement was made during the trawling expeditions of 1884, and, with the aid of Lord Dalhousie and the Fishery Board for Scotland, a systematic examination of such forms as were available was begun at the St. Andrews Marine Laboratory, and it was fortunate that, shortly afterward, the aid and coöperation of Prof. E. E. Prince, now Commissioner of Fisheries in Canada, were available.

On the present occasion I shall devote my remarks to the mention of those fishes which for the first time have been hatched at the St. Andrews Marine Laboratory—the oldest institution of the kind in Great Britain.

No pelagic egg is more abundant on the east coast than that of the grey gurnard (*Trigla gurnardus*), and it is quite easy to fertilize ripe eggs from the females and hatch them in the tanks. The larvæ are hardy, and in open-air tanks communicating with the sea could readily be reared to the young stages. The minute characters of the egg, larvæ and young stages have been described and figured in the publications emanating from the laboratory, and the same remarks apply to the subsequent forms.

The armed bullhead (*Agonus cataphractus*) deposits its demersal eggs on the bottom of the bay and on stones, while the larvæ and young are only common in the bottom nets. The ova are easily hatched in the laboratory, and the bright colors of the young are characteristic.

The floating gelatinous ribbands containing the ova of the frogfish (*Lophius piscatorius*) are less frequently encountered on the east coast than one would expect. It is possible, however, that the constant destruction of the adults in the stake nets and in trawls may account for the comparative rarity of the ova. Isolated eggs are occasionally obtained in the tow nets, but the best examples of the developing ova were procured from the salmon stake nets off the east rocks, and the larvæ have been carefully figured and described by Prof. Prince.

The demersal eggs of the spotted goby (*Gobius minutus*) have occasionally been found on stones, and more frequently in the valves of *Solen siliqua*, *Lutraria*, and other mollusks. They have been described by Mr. E. W. L. Holt, who has also carried on able researches at the St. Andrews Laboratory. The young are very abundant.

The small but beautifully reticulate pelagic ova of the dragonet (*Callionymus lyra*) are not uncommon in the tow nets all along the eastern and western shores. They were first described in 1885, and have frequently been hatched in the tanks. The larvæ have been described both by Prof. E. E. Prince and Mr. Holt. The very young stages are frequently observed in the bottom tow nets; indeed, all stages have been thus procured. The abundance of black pigment on the ventral surface of the young forms is one of the most striking features.

The masses of the demersal ova of the lump-sucker (*Cyclopterus lumpus*) are very abundant in spring off the rocky shores, and the remarkable devotion of the males in guarding the eggs is not surpassed by any other form. Many so expose themselves amongst the tidal rocks close to the eggs at low water that crows pierce their sides and devour them alive after picking out their eyes. The eggs are easily hatched in the tanks, and the larvæ and young are very hardy. They likewise abound in the tidal pools and in the inshore waters amongst floating seaweeds. Instead of being thrown away as manure, the multitudes of adults might be utilized for making mock-turtle soup. Their thick gelatinous skins are well adapted for this purpose.

One of the earliest demersal eggs of the season is that of Montagu's sucker (*Liparis montagui*) which occurs in clusters on *Delesseria* and other seaweeds and on zoophytes all along the east coast. The larvæ in the tanks are as lively as those of the lump-sucker—shooting through the water like swarms of ephemeræ in the air.

The largest marine demersal egg hitherto met with in Great Britain is that of the wolf-fish (*Anarrhichas lupus*) a huge mass of which was brought to the harbor by a local trawler early in 1886, and subsequently hatched in the laboratory. The ova are only a little less than those of the salmon—for which the local fishermen mistook them, but they differ wholly from that species, not only in regard to the single large oil-globule, but in the fact that the ova are fixed to each other in masses. The large larva is one of the most interesting forms in the group. The skins of the adults should be utilized for leather, as in the case of the Norwegian species.

The eggs of the gunnel (*Centronotus gunellus*) are often met with in spring as masses in holes of the rocks near low-water mark, the female fish generally enveloping them in a coil of the body, and the same feature is observed when the eggs are deposited in the tanks. They are hardy, and the larvæ and the young are also easily kept in confinement.

The demersal ova of the 15-spined stickleback occur in nests formed of seaweeds in the higher littoral parts, and they also are readily hatched in confinement, as detailed by Prof. E. E. Prince.

The pelagic ova of the cod—procured during the trawling expeditions of 1884—were among the earlier forms treated at the laboratory, and every year since have been under observation. The same may be said of the eggs of the haddock and whiting.

The pelagic eggs of the poor cod (*Gadus minutus*) have also been frequently under observation, but fertilized eggs about which there could be no doubt have only recently been obtained, as detailed in the accompanying pages.

The pelagic ova of the ling have been fully described and the larvæ and subsequent stages figured. The ripe ova and milt were obtained from the distant offshore waters by the long-liners, and though the surroundings of the jars were by no means favorable in the fishing boats no difficulty was experienced in conveying them to the laboratory for hatching.

The pelagic eggs of the torsk (*Brosmius brosme*) in a fertilized condition were only recently procured from Shetland, and are distinguished by their pinkish oil-globules, as described in the following pages.

Great uncertainty prevailed concerning the eggs of the sand-eels, both larger and smaller, but it has been found that the ova are demersal and adhesive, probably sticking to sand or other substance in the sites frequented by the adults. The eggs of the larger sand-eel (*Ammodytes lanceolatus*) have a deep-greenish oil-globule, that in the eggs of the lesser sand-eel being paler and with a pinkish hue. The larvæ have long been known, and occur in great numbers in the bottom tow nets. They also, however, at a somewhat later stage are occasionally found at the surface.

The pelagic eggs of the long rough dab (*Hippoglossoides limandoides*) have been familiar since 1884, and every season have been hatched at the laboratory. The egg is remarkable for the size of the perivitelline space, which gives it a large diameter.

The pelagic ova of the brill have been successfully hatched, and the boldly colored larvæ described. The difficulty is to get a sufficient number of ripe ova and a suitable male for fertilization. The egg has a single oil-globule.

The pelagic eggs of the sail-fluke (*Arnoglossus megastoma*) also have a single oil-globule, and they and the larvæ are described in the following part of this paper.

The large pelagic ova of the plaice have long been familiar at the laboratory as one of the earliest captures of each season. The ova are hardy and the larvæ are easily reared. The growth of the young is comparatively rapid.

Large numbers of the pelagic ova of the lemon dab (*Pleuronectes microcephalus*) have frequently been hatched, and the larvæ reared to the late stages. There should be little difficulty in rearing this species in suitable open-air tanks.

The small but ubiquitous pelagic ova of the dab (*Pleuronectes limanda*) have been familiar every season since 1884. They are hardy and so are the larvæ. The same remarks apply to the eggs of the flounder (*Pleuronectes flesus*), which can survive considerable changes in the temperature of the water.

The pelagic ova of the sole (*Solea vulgaris*) were first observed in the trawling expeditions of 1884, and have been found every season in the bay when carefully looked for. The eggs and larvæ are very hardy, and experiments on a larger scale at Dunbar will soon be made with both.

The transparent pelagic eggs of the sprat (*Clupea sprattus*) occur in enormous numbers every season. They are easily hatched in the tanks.

The eggs of many other fishes have, moreover, been examined and most of them described, such as those of the short and long-spined *Cottus*, bimaculated sucker, shanny, Yarrell's blenny, viviparous blenny, 3-spined stickleback, bib, green cod, pollack, the rocklings, halibut, turbot, Müller's topknot, salmon, gar-pike (ovarian), minnow, conger (ovarian), twaite-shad (ovarian). Further information has been gained about eggs which had been hatched elsewhere, such as the lesser weever, rockling (*Motella mustela*), little sole, herring, and others, besides the young of various skates, dogfishes, and the viviparous blenny.

Besides the study of the living eggs, larvæ, and young fishes, large collections of preserved pelagic ova, larvæ, and young fishes have for several years received special attention. They are made by the *Garland*, the ship used by the Scotch Fishery Board for scientific observations, according to special instructions, and the ova are preserved in 4 parts alcohol, 4 parts acetic acid (2 per cent), and 1 part camphor, after being killed in a saturated solution of picric acid in 5 per cent hydrochloric acid; the larvæ and young fishes are killed by a saturated solution of corrosive sublimate, washed, and then placed in methylated spirit, and changed if many are in one tube or bottle. By careful study and comparison the nature of many of the ova can be made out, and the numbers of each in the respective areas determined. The nets of course, are kept down for a fixed period, and both surface and bottom nets are used simultaneously. By summing up the results of the trawl and of the contents of the tow-nets, the condition of the several areas in regard to food and other fishes is determined with considerable accuracy, while the occurrence and distribution of ova are also observed.

II.—ON THE HATCHING OF MARINE FISHES IN RELATION TO THE FISHERIES.

Though from the foregoing remarks it will be seen that most of the important food-fishes have been hatched at the St. Andrews Marine Laboratory, yet it can not be said that in this country the hatching of such fishes has been carried out on a large scale. The Fishery Board for Scotland have nearly completed an establishment of this kind at Dunbar (see pp. 257–262), and fishes have been collected for next season, but no actual hatching on a large scale has occurred. The importance of the issue demands that a thorough trial be made, though it has not yet been proved that the artificial hatching of sea fishes will be beneficial to the fisheries generally. In performing experiments of this kind it is best to select a fish not only suitable and hardy, but one comparatively rare in the vicinity of the hatchery, if not entirely foreign to the area. The increase of such a fish after the operations can not thus be mistaken. For example the sole (*Solea vulgaris*) has been selected as the best fitted for experiment at Dunbar, since comparatively few exist in the neighborhood, and the larvæ and young are hardy. The same species has been chosen for experiments in transporting the adults and adolescents into new areas, such as St. Andrews Bay, into which several hundred were placed this autumn. The plaice (*Platessa vulgaris*) will also be hatched at Dunbar. For experiments of the first-mentioned kind the fjords of Norway are admirably adapted, since constant fishing has greatly thinned the native cod (a small variety). If, therefore, Capt. Dannevig can show that his millions of larvæ, which for some years have been sent into the water, have had the effect of increasing the number of cod captured by the fishermen of the locality, a strong case will have been made out.

So far as we in this country can judge, the American experiments have not resulted in anything very definite in regard to sea fishes. It is doubtful, however, if the scale on which such experiments have been conducted has been sufficiently large to merit confidence. Again, we are in want of accurate data to guide us in regard to the period at which the fishes ought to be freed; that is to say, whether they should be placed in the sea just before the yolk-sac is absorbed or retained in large open-air inclosures until they are adolescents. The difficulty of making the inclosures precisely resemble the open sea in their pelagic fauna and flora (both of which are so closely related to the well-being of the fishes) is well known; indeed, no perfect substitute for the open sea can be found. Further experience, however, may enable us to overcome many of these difficulties.

III.—FURTHER REMARKS ON THE DEVELOPMENT AND LIFE-HISTORIES OF THE FOOD-FISHES AT THE ST. ANDREWS MARINE LABORATORY.

ON THE EGGS AND LARVÆ OF THE POOR COD (GADUS MINUTUS).

Raffaele[*] briefly alludes to the egg and larvæ of this species, which seems to be one of the most ubiquitous gadoids, ranging from the Mediterranean to the North Sea, remarking that the former (eggs) agree in general structure with those of the cod, but that the larvæ differ in the arrangement of the pigment. Marion[†] also found a large number of ova in the Gulf of Marseilles, on the 7th March, which he considered were those of the capelan (*Gadus minutus*), and he gives a figure of the larva. Lastly, Mr. Cunningham states that in April he found this species ripe at Plymouth, the diameter of the ova 1.02 mm., and the perivitelline space small. He did not hatch them.

For several years the spawning of this species has been under consideration, but a more or less complete account has only been obtained recently. In 1884 and 1885 many ripe females were seen, but no ripe male was available at the same time. By the skill and care of a fisherman at St. Andrews (James Gourlay) numerous fertilized ova were brought from the neighborhood of the Bell Rock in June last year (1892). The nearly ripe ovarian egg has, as usual, a denser capsule, which, moreover, is wrinkled. In diameter the ripe eggs ranged from ·9906 mm. to 1·0287 mm., sizes extending on both sides of the average given by Mr. Cunningham. And the series of ova procured in the open sea off Aberdeen were from ·9525 to ·9906 mm., and were thus somewhat less than the preceding. Only a very few reached 1·0287 mm.

The development was comparatively rapid, as might have been anticipated in the warm weather. Ripe ova fertilized at 9 a. m. on the 6th June were in the multicelled condition at 5.45 p. m., with a well-marked perivitelline space. The temperature at this period rapidly increased, so that considerable mortality ensued. Indeed, the mere handling of the water containing them under the miscroscope killed the embryos, which on the 7th were outlined and the optic vesicles indicated.

The eyes of the advanced embryos are silvery (one of the most characteristic features of the egg), and yellowish pigment is scattered over the head, body, and yolk. The young larva somewhat resembles the whiting in coloration and measures from 2·2 to 2·4 mm. The eyes are silvery greenish, and the entire head and body are dappled with minute yellow specks, invisible under a lens, but seen by transmitted light under a low power of the microscope. Black chromatophores occur along the ventral border of the muscle-plates, the tip of the tail alone being free. A less distinct series lies along the dorsal edge, and a few finely branched specks exist on the head. The rectum terminates blindly at the posterior and upper part of the yolk, which seems to be comparatively large. Thus in a specimen with the tail slightly shortened (by curvature) the total length was 2·4 mm., while the yolk-sac from its anterior to its posterior border was 1·2 mm.

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[*] Mittheilungen Zool. Stat. Neap., VIII Bd., 1 Heft, sep. abth., p. 36, tav. I, f. 25, et tav. 2, pp. 20, 21, 1888.

[†] Ann. du Musée d'Hist. Nat. de Marseilles, Zoolog., IV, p. 188, pt. 2, fig. 14.

Five days after hatching stellate black chromatophores appear on the yolk-sac and along the sides of the body, only terminating near the tip of the tail. The yellow chromatophores are also more evident on the yolk-sac. The otocyst shows a double border. The position of the rectum is almost unchanged. The yolk-sac soon diminishes and the growth of the branchial arches, gill-slits, pectorals, and other parts is apparent, while the mouth opens.

Two days later the yolk in some had quite disappeared, and the mouth is widely open, though the mandible is as a rule rigid. The pectorals are large fan-shaped blades and are carried upward. Even before the yolk has been absorbed the larvæ swim on edge, resting afterwards on the side. The eyes are silvery on the bottom by reflected light, but have a gorgeous bronzed hue by transmitted light. In the older examples the yellow pigment seems to be less conspicuous, for it is present only on the head and anterior region, with a few specks on the pectorals. The increase of the black pigment over the abdomen is noticeable. The circulation of the colorless blood is visible in the dorsal aorta and the cardinal veins. The swim-bladder is well marked. They constantly dart about with open mouth, seldom resting more than a second or two, so that delineation is difficult.

At a slightly later stage the yellowish pigment had disappeared except from the cheeks, and the pectorals had increased in size. The marginal fin became vesicular; indeed the specimens were comparatively delicate, often perishing if placed in water on a slide. A few survived till the 24th June without presenting any noteworthy change except the appearance of a dorsal and a ventral skeletal bar representing the shoulder girdle.

ON A PECULIAR EXAMPLE (HYBRID?) OF THE POOR COD (GADUS MINUTUS).

A fisherman procured by a hook on the 24th March a fish which he and others supposed to be a hybrid between the whiting and the bib, or between the former and the poor cod, and he sent it to the laboratory.

The extreme length of the specimen was 7½ inches, and the greatest depth 1½ inches. In general outline it somewhat approached the whiting, though the dusky bronzed pigment of the dorsum and dorso-lateral regions, the somewhat coarser scales, together with the shape of the head, the presence of a barbule, and the condition of the pelvic fins leaned to the poor cod. Yet it distinctly differed from the latter in general aspect, and in the much more silvery infero-lateral regions and abdomen.

In regard to the shape of the body and the course of the lateral line it most nearly approached the poor cod, though it was more elongated. Moreover, the curve of the lateral line kept at a nearly uniform height, or even with a tendency upward till beyond the tip of the pectoral, and the downward curve was decidedly more abrupt. It differed in this respect not only from the poor cod, but from the whiting and the bib. This curvature may be related to the marked depression in the dorsal outline from the posterior border of the first dorsal fin to the middle of the second, but it is not connected with any abnormality of the vertebral column.

The fins agreed more or less with those of the whiting, the first dorsal especially differing from that in the poor cod and bib, and corresponding rather with that in the whiting, since it was much less acutely triangular and much less elongated. It possessed 14 rays (Day attributing 12 to 15 to the poor cod). The second dorsal corresponded generally with that in the last-mentioned species, and it had 22 rays (Day giving 19 to 25). The fin rays, however, were less uniform. The third dorsal had 25 rays (Day, 17 to 22) and resembled that in the poor cod. The first anal commenced in a line with the posterior border of the first dorsal, and extended slightly beyond the commencement of the third dorsal. The longer rays anteriorly, and its general shape, approached the condition in the poor cod. It had 27 rays (Day, 25 to 28). A vertical line from the posterior border of the first dorsal touched the commencement of this fin, whereas in the whiting a considerable portion of the first anal was in front of the line. The second anal had 26 rays (Day, 25 to 29).

The caudal had a somewhat larger "bite" in the middle than usual, and had 30 rays (Day, 26). The pectorals require no special remark, except that the black spot at the base was more pronounced than in the poor cod, but corresponded neither with the bib nor the whiting, being less distinct than in the former, and larger than in the latter. It proceeded nearly to the middle of the base, instead of being confined to the region above the base. There were 18 rays in the pectorals (Day, 13 to 16). The pelvic fins agreed with those in the poor cod, each having 6 rays.

When viewed from the dorsum the snout was considerably narrower than in a poor cod of the same length. In profile, also, the head was more elongate, the mandible especially differing, since it projected in front beyond the premaxillaries. The eyes were considerably smaller than in an average example of the poor cod, and the loose corneal covering was less developed. The barbel was comparatively small.

The specimen was a female, with the ovaries even more advanced than in an ordinary example of the species, and it would certainly have spawned this season. The ova ranged from ·3810 mm. to 1·1430 mm.

The teeth differed from those of the poor cod and the bib, being nearly uniform; that is, the larger teeth of the outer row, usually so characteristic, were not distinctly differentiated. They diverged still further from the teeth of the whiting. There were 37 gill-rakers in the outer gill, 24 in the next, 23 in third, and 18 in the inner, all thus diverging from the average condition in the poor cod.

On the whole the differences warrant notice, especially as these became even more marked after preservation in spirit. Instead of the pale-brownish and somewhat loose, wrinkled skin of the dorsum and lateral regions of an ordinary preparation of a poor cod, this presented slightly darker pigment on a smoother surface (smaller scales). The region below the lateral line was also much smoother, and, moreover, the firm surface had a sheen as silvery as in the whiting.

ON THE EGGS OF THE COALFISH (GADUS VIRENS).

Some remarks were made last year* on the unfertilized eggs of this species, and the continued exertions of Dr. Fulton and the staff of the Fishery Board have enabled me to add to our knowledge of this species. In a ripe female the ovaries are characterized by walls of considerable thickness, so that at first sight they resembled those of the wolf-fish, more especially as they were very distinctly connate. In section the ovarian wall appeared to have a well-marked circular coat, then a thick layer of longitudinal fibers, followed by a somewhat mixed inner series, chiefly circular, but also containing numerous longitudinal fibers. The belly in this sex at maturity is prominent (a feature specially noted by Mr. Holt), as in the cod, pollack, and others.

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*Tenth Annual Report of the Fishery Board for Scotland, III, p. 287.

On March 31 Mr. R. Duthie, assistant fishery officer at Lerwick, Shetland, skillfully fertilized a series of ova at 4 p. m. and transmitted them to St. Andrews. At 6 p. m. on April 3 all seemed to have perished, but a more careful survey of the demersals showed that there were some living eggs on the bottom. These had a diameter of 1·0287 mm., whereas others from the same fish, imperfectly preserved in weak picric and spirit, had a diameter of 1·1430 mm. The general appearance of the egg resembled that in the cod, and the micropyle agreed with that of the haddock. The blastopore was still open, and the optic vesicles had formed. The perivitelline space varied in size.

On April 4 the blastopore had closed (with radiate streaks) and Kupffers' vesicle had formed. The muscle plates were defined and the notochord more evident. The yolk presented a faintly granular aspect, perhaps from indications of the future pigment corpuscles. The pectoral folds are large and show many granules. The radiate strands of the latter region had become only distinct on April 6, and black chromatophores had appeared over the yolk, while indications of similar pigment were present along the body. The black chromatophores had generally increased on April 7, though there were variations in this respect. On the 8th the sides and yolk-sac of the embryo had a series of conspicuous black chromatophores, and the tip of the tail now reached the head. The arrangement of pigment thus prominently differs from that in the cod and foreshadows the more general distribution of the chromatophores so characteristic of the species in the young condition. One hatched on April 9, the color being similar to that described in the advanced embryo. All the eggs remained throughout on the bottom of the vessel, but retained vitality.

It is remarkable that so few opportunities of seeing the fertilized ova of this species have occurred, and yet it is a common form on the eastern and western coasts.

REMARKS ON THE EGGS AND YOUNG OF THE HALIBUT.

The ripe females of this species seem to have been met with chiefly toward the end of April and beginning of May. Those observed last year* were procured on the former date, those of this year on the latter, viz, on the 5th of May. It was thought last year, from the condition of the specimens, that the *zona radiata* of the eggs in this species was delicate; such, however, is not the case.

In size they are among the largest pelagic eggs known, ranging from 3·0861 to 3·8 mm. Raffaele, in the Bay of Naples, appears to have found none over 3 mm. in diameter, though Wenkebach subsequently procured one of 4 mm. The capsule (*zona radiata*) shows faint scribbled markings, as first mentioned by Mr. Holt, who obtained the eggs at Grimsby about the beginning of May last year. In those from Bergen Bank the markings resembled fine creases or folds, which sometimes even assume a stellate arrangement like those of the lemon dab or brill. The usual minute punctures occur all over the surface. The folded edge of the *zona radiata* is marked by closely arranged striæ, an appearance often seen in the shriveled eggs of other species. A simple micropylar orifice only occurred, without surrounding lines, and it generally presented a pinkish hue, probably from refraction, as in the large pores in the egg of the torsk. This form has been included under the pelagic eggs, both from its appearance and structure, but since it has never been obtained in a tow net in the neighboring seas it is possible it may be less buoyant than the smaller eggs.

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*Tenth Annual Report of the Fishery Board for Scotland, part III, p. 285.

The larval and post-larval stages of the halibut have hitherto escaped notice. A form procured by the *Garland*, on Smith Bank, in June, 1889, off the coast of Caithness, however, approaches what is conceived to be the type of this genus. It is distinguished by the great thickness of the body (the depth of which, moreover, is comparatively moderate), by the character of the head, and the presence of branchiæ projecting behind the opercula. It is not a very young fish, to judge from the thickness and firmness of the body and the condition of the branchiæ, yet the embryonic tail (opisthure) is still present. The total length is 9·5 mm., and the greatest depth is about 3·8 mm. The vent is situated a little in advance of the median line of the body, which is speckled with minute brownish-black points (in spirit) on the head and lateral regions, and by similar specks over the abdomen, the latter chromatophores, however, having undergone considerable change from the spreading out of the marginal pigment, while a black speck remains in the center. The chromatophores on the lateral region are somewhat regularly arranged. Indications of two pigment-touches occur in the dorsal (marginal) fin, viz, one above the tip of the pectoral, and the other about the center of the first abdominal region of the body. Ventrally a single patch is situated midway between the anus and the hypural region. The pigment invades the fin, and thus resembles that in the pleuronectids generally. On viewing the dorsum from above, the cephalic and the two marginal touches, which extend to the fin, are best seen. Ventrally a little pigment over the abdomen and the patch in the anal fin are noticeable, while chromatophores are dotted round the anus. The pigment is alike on both sides.

The eyes are of considerable size and are lateral in position. The marginal fin is injured, but seems to have been of moderate depth, traces of true rays appearing both dorsally and ventrally, and particularly in the caudal. The terminal curve of the notochord is pronounced, but does not taper much, and the embryonic fin forms a shorter lobe than in the pleuronectids hitherto examined. A few black specks occur inside the abdominal cavity.

The thickness and elongation of the body of this specimen suggest its relationship to the halibut, yet nothing in its structure would militate against its being another form. I am inclined, however, to connect it with the species mentioned.

Specimens of the young halibut are extremely rare, perhaps because they are found only in deep water on the great fishing-grounds. The smallest examples hitherto examined here were two from St. Andrews Bay, the larger being a foot long. They were obtained by a local trawler, but similar specimens are occasionally caught on lines. Last year a specimen, apparently of this species, was procured in the deeps about 50 miles from Norway on May 31, measuring 97 mm., or a little over 3¾ inches. It had been swallowed by a green cod. The fin formula is D. 97, A. 73 (?), caudal 19, pectoral 11, pelvic 6, though it must be stated that digestion had considerably affected the fins.

The chief differences between this and an example 1 foot long are the proportionally larger size of the eyes and their proximity to the anterior border of the snout—the smallness of the gape—the posterior angle of the mouth being somewhat in front of the eye; whereas in the larger (1 foot) it passes to the anterior fifth of the eye, and the maxilla is boldly marked. The arch of the lateral line behind the eye on the right side is much more pronounced in the larger specimen, for in the smaller it is gently curved upward and runs forward with a very slight declivity. On the left side the arch is more distinctly curved. Variations, however, are frequent in the larger examples. The caudal rays proceed from a nearly vertical line in the smaller specimen, but from a semicircle (*i. e.*, a line convex backward) in the larger. The opercular region also differs, but the action of the gastric juice had made changes in the small specimen. The thickness and narrowness of the body are more or less diagnostic at this stage.

ON THE EGGS AND LARVÆ OF THE TORSK (BROSMIUS BROSME).

The literature on the spawning and development of the torsk is very meager. Thus, Couch says it comes from deep water near the coast at the time of spawning, which is in January and February. Parnell, again, states that it spawns in April and May amongst the seaweeds along the coast. Day, like Parnell, seems to have copied this remark without query. Brook, in the Report (1886) of the Fishery Board for Scotland gives, on the authority of the fishery officers, March at Wick, May and June at Peterhead, and the same two months at Berwick. Dr. Fulton, who examined two very fine specimens of 34 inches, and weighing, respectively, 15 pounds 5½ ounces and 15 pounds, calculated that the partially developed ova in the former were about 2,283,979 in number, whereas in the latter, which, he thinks, had discharged part of them, the ovaries contained 790,064. In the latter example, 40 or 50 in 3,612 ova which were counted were large clear eggs, having a diameter of 1·4 to 1·32 mm.

Little was known of the breeding of the species, though from its relationship with the ling and the rockling it was supposed to have an egg with an oil-globule. Various attempts had been made by the Fishery Board for Scotland and others to secure ripe examples, but without success. The energetic efforts of Dr. Fulton and the fishery officers (among whom must specially be mentioned Mr. Mackie, assistant officer at Peterhead, and Mr. Duthrie, assistant officer at Lerwick) at last solved the difficulty. Mr. Mackie procured ovarian eggs, the latter a fine series of fertilized ova. In the ovarian ova a number of unripe were mingled with others more or less ripe, the diameter of the latter in a fluid consisting of one-half saturated solution of picric acid and half spirit, ranging from 1·2573 to 1·3335 mm., the latter being approximately the average of ripe eggs after preservation. The ripe fertilized eggs, the securing of which under many difficulties reflected great credit on Mr. Duthrie, were got on the 25th of May. He had less trouble in obtaining females; it was the condition of the males which puzzled him; for the spermaries are small, reaching in the proportions only from 2 to 3 inches in a male of good size, and having the form of a small frilled cord or ribband. They thus differ materially from the condition in the cod and its allies.

The ova on their arrival from Shetland were almost dry, and their hardihood was, perhaps, partly due to the fact, so often seen in other forms, that they had reached a certain stage of development, viz, the fourth day. They had an average diameter of 1·3335 mm., so that the preserved examples from Peterhead must have been exceptionally fine or had been slightly dilated. The large oil-globule, which had a diameter of 0·2286 to 0·2667 mm. appeared, under the lens, of a pale reddish-brown hue, but by transmitted light of a pale red; indeed, no pelagic egg, with the exception of the sand-eel, has presented a more distinctive color. In some a series of minute fatty granules were also present under the large globules. The *zona radiata* is remarkably tough and resistant, and the egg can only be ruptured by the exercise of considerable force. A series of boldly marked punctures are present and they have in some views a slightly pinkish hue from refraction, while under a high power they give the capsule a minutely punctured appearance. If a fragment of the *zona* be dried on a slide, each of the punctures enlarges and becomes the center of a curiously wrinkled margin with numerous processes, such as might have been due to protoplasmic environment. This appearance was, however, probably due to the wrinkles or folds of the dried *zona*. The latter in the fresh examples is further marked by faint lines or creases, which in some are crossed by another series of similar lines, so that it resembles the *zona* of the brill, lemon dab, and sail fluke. The micropyle is very evident and after the plan of that in the haddock; the external aperture, which is in the center of a depression, is smaller than the internal.

On the fourth day, when the eggs reached the laboratory, the blastopore was closing or closed, the optic vesicles formed, and a broad alar expansion was present on each side. The perivitelline space was small. Development proceeded normally, so that two days later a number of myotomes were formed laterally, besides lenses and otocysts, while slight contractions occurred in the heart. A considerable portion of the tail was free, and a few simple pigment-specks were scattered over it. The embryo jerks body and tail. Next day (May 28) black chromatophores were studded along the sides of the body and the head, and some on the latter and in the proximity of the pectorals were slightly stellate. Each otocyst had two otoliths. The pectorals projected outward as rounded lobes. The tail was much elongated and had a group of black chromatophores at the tip. The perivitelline space was larger. All the ova lie on the bottom of the vessel.

Before hatching, a greenish yellow hue (by transmitted light) appeared on the head and the tip of the tail. Some emerged on May 30 before noon (ninth day after fertilization). The larva measures about 4 mm. and is characterized by the large pinkish-brown oil-globule, which is generally fixed at the posterior border of the yolk. In some, however, the oil-globule was freely movable, a feature which had not hitherto been observed in such larval forms. By depressing the tail of the larva the oil-globule glides forward to the middle of the yolk, and by elevating the head it mounts to the highest point, viz, the anterior border of the yolk. Nothing could better illustrate the features formerly pointed out in regard to the movement of the oil-globule in the gurnard,* and the passage of the brightly colored globule through its yolk (and not merely at the surface of the yolk as some thought) was in this instance easily followed.

The free condition of the oil globule of the larval torsk in these instances was probably abnormal, but it is worthy of note. Five conspicuous black touches or bars further distinguish the larva, viz, one on the head and four on the body. The chromatophores on the head are somewhat irregularly scattered, though a front view of the head in the egg shows that a more or less symmetrical series occur over each eye. The first patch or bar on the trunk is placed rather behind the middle of the yolk, though a little variation exists, and it is rendered the more conspicuous as the black pigment of the subnotochordal region exists beneath. The chromatophores in this and the other areas are very finely ramose. The next patch or bar lies on the muscle-plates behind the yolk; the last is at the tip of the tail, while a less definite one is intermediate. As already mentioned in connection with the embryo, the larvæ have a slightly yellowish hue (greenish by transmitted light) on the head, yolk-sac, and the tip of the tail. The rectum is high up on the marginal fin, with the lumen just within the tip. The urinary vesicle is distinct. The notochord is multicolumnar. The surface of the yolk-sac, the pectorals, and the marginal fin are minutely vesicular. A little black pigment appears in the eye. The healthy larvæ are active.

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*Trans. R. Soc. Edin., vol. 35, p. 687.

Next day (May 31) the chief feature was the increase in the greenish-yellow hue on the under surface of the head, on the yolk sac, and the tip of the tail, this hue being due to the development of the cutaneous vesicles formerly mentioned, and it makes a bold contrast with the pinkish oil-globule. The ramifications of the black chromatophores have everywhere increased, those at the tip of the tail having a radiate arrangement like fin-rays. The liver appears on the ventral border of the gut, while the rectum has moved downward a little and often contains a round mass. The pectorals and otocysts are larger. In one a peculiar abnormity occurred, viz, the presence of a long narrow process—resembling a diverticulum—in the rectum, which in this instance had reached the somewhat defective border of the fin.

The changes which were visible on June 1 consisted of the projection of the cartilages of the mandible, increase of pigment in the eyes, and the passage of the rectum, with the urinary vesicle near the fin-margin. The little fishes are restless, and the use of the pectorals in balancing is more evident. The yolk has considerably diminished. Next day the eyes showed a greenish silvery luster, and peristaltic movements occurred in the gut. Moreover, though the mouth is still closed, spasmodic movements of the mandibular region take place. As in the cod, rockling, and other forms, the black chromatophores, when seen against a dark background under a lens, look brownish.

June 3 the larvæ were characterized by their activity, and especially by the rapid vibration of the pectorals. Only a small anterior portion of the yolk now remained, while the reddish-brown oil-globule has been drawn forward and almost concealed under the greatly increased black pigment of the upper region of the abdomen.

About a week after hatching (June 6) the larvæ swam more readily, and the mouth had opened—the mandible being moved up and down with the hyoidean apparatus. The yolk was almost absorbed, only a trace of the oil-globule being visible. The rectum had not yet reached the border of the marginal fin, but it was close to it and its margin was papillose. Little change had taken place in the pigment of the body, but the caudal patch had spread out in a characteristically fan-shaped manner (coincident with the development of embryonic rays in the tail) and the yellowish tint of the marginal fin in the same region had somewhat increased. The caudal region of the marginal fin seemed to have diminished. They are hardy larvæ, and could without much difficulty be reared in large numbers in a suitable inclosure.

ON THE DEVELOPMENT OF THE SAIL-FLUKE (ARNOGLOSSUS MEGASTOMA).

The earlier ichthyologists do not appear to have seen a ripe sail-fluke or "megrim," as it is often termed by the Scottish fishermen. No information on the subject is given by Parnell and Couch. Day observed that "Thompson, on October 31, at Belfast, procured one which had just shed its ova, only a few mature ones remaining." Raffaele* pointed out that the ova of *Arnoglossus* have a single oil-globule, and his figure on the whole resembles the present species, except that he does not show the minute structure of the *zona radiata*. His figure of the larval *Arnoglossus* (tav. 4, fig. 20), however, differs materially from that of *A. megastoma*, both in structure and coloration; and it is unknown whether the careful Italian author refers to *A. laterna* or another form. He represents the post-larval *Arnoglossus*, again, with a long ray like a flagellum anteriorly.

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* Le uova galleggianti, etc., Mit. a. d. Zool. Ital. zu Neap., III Bd., 1 Heft, 1888, sep. abd., p. 49.

Mr. Holt*, who found ripe forms of both series in March, April, and May, states that the eggs are very translucent, have a diameter of 1·08 to 1·13, and possess a single oil-globule, ·30 mm. in diameter. He thinks, from his observations off the west coast of Ireland, that spawning takes place only in moderately deep water, and necessarily therefore at some distance from shore, always at a great distance from the coast when the declivity is very gradual. On the eastern shores of Scotland the species is an inhabitant of the deeper water.

Three series of ova reached the laboratory in May, 1892, but it will be sufficient to allude only to the last, which were at an early stage of development on the 28th of May at 11 a. m. They had a diameter of 1·1430 mm., while the oil-globule measured ·3048 mm. All the living eggs were remarkably buoyant and had a perivitelline space. The *zona radiata* conforms to the type seen in the brill and lemon-dab, being covered with raised lines or ridges with very fine striæ between them. The usual minute punctures densely cover the surface. The micropyle is difficult to distinguish, but it appears to be sometimes situated in the center of a radial series of lines in a space bounded by other ridges. It is best seen by setting several eggs together in a cell, so that they support each other and give special positions unattainable when each is free.

On the 29th May (next day) the rim had either reached the equator or extended beyond it, and a dimple was often present on each side (in optical section) where the rim constricted the yolk. The following day (30th May) the embryo was fully half round the yolk and the perivitelline space had increased. The lenses are now present, and black chromatophores appear under the oil-globule and in the caudal region.

Further changes before hatching were the increase in the perivitelline space from the diminution of the yolk, the ramifications of the chromatophores under the oil-globule and on the tail. Black pigment also appeared along the sides of the embryo. Larvæ were hatched on the 1st June, perhaps prematurely. They possess only black pigment, which is somewhat uniformly scattered over the body with a few specks on the head, and it also occurs both dorsally and ventrally in the marginal fin. Thus five or six V-shaped chromatophores are found near the margin of the dorsal fin behind the yolk-sac—almost intermediate between it and the tip of the tail, and two similar or somewhat triangular ones opposite the former ventrally. The large oil-globule lies at the posterior and inferior part of the yolk. The otocysts are simple sacs. No pigment exists in the eyes. The notochord is multicolumnar. The solid strand of the rectum comes to the edge of the marginal fin, and a pre-anal portion of this fin is present. The urinary vesicle shows only a small central chamber. The oil-globule in lateral views is somewhat elliptical.

Two days afterward (June 3) yellow pigment was apparent amongst the black in the marginal fin, and along the sides of the body posteriorly. The yolk-sac, as a rule, has no chromatophores, one or two only occasionally being situated at the upper part of the region. The enlargement of the otocysts, liver, and other organs is considerable, and the skin is minutely vesicular. In larvæ which only escaped at this date (June 3) the yellow pigment was not noticeable on the caudal region.

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* Report of Council, Roy. Dub. Soc., 1891, p. 238.

The mouth seemed to open comparatively early, since it formed a conspicuous aperture on June 6. It differs considerably from that of the gadoids, as the mandibular cartilages are much less developed, yet it is proportionally large and the movements extensive. The pericardial chamber was very large in the eyes on the 7th. The large pectorals are used for balancing. Black pigment was developed. The skin is minutely vesicular, and the canary-yellow pigment is conspicuous in the posterior part of the body.

REMARKS ON THE DEVELOPMENT OF THE BRILL.

Some remarks were formerly made* about the development of the ova of the brill fertilized with the milt of a turbot. A further series fertilized with a male of the same species was obtained on May 22, 1892. They had a diameter of 1·3335 mm., the oil-globule measuring ·2286 mm. The latter behaved as in the gurnard, rolling under the periblast and beneath the disk, and passing through the yolk when suddenly inverted. Without going into minute details it may be stated that on the 27th the embryo had lenses and otocysts, the tail projected from the yolk, while a yellowish hue pervaded the head, body, and yolk-sac from the development of numerous chromatophores. So numerous are these over the yolk-sac that it seems to be densely speckled all over with minute yellow grains. Black chromatophores are likewise present on this as well as on the body. The remarkable development of the deep brownish-yellow pigment is one of the characteristic features of the species, and the fact was elicited that the milt of the male turbot did not seem to have made any striking variation in hue, so far as could be observed in the embryo and larva.

LIST OF PAPERS.

The following list of papers published in connection with the St. Andrews Marine Laboratory might properly include the work on the Invertebrate Marine Fauna and Fishes of St. Andrews† and numerous papers published since 1861:

List of published papers dealing with work done at St. Andrews Marine Laboratory from the opening of the Laboratory in 1884 up to and including 1892.

1. Report I to the Fishery Board for Scotland, 1884.
2. Report on Trawling at the request of Lord Dalhousie, chairman of the Trawling Commission, 1884–85.
3. Report II to the Fishery Board for Scotland, 1885. (1 plate.)
4. Report III to the Fishery Board for Scotland up to 31st December, 1885.
5. Report IV to the Fishery Board for Scotland (year 1886), 1887. The foregoing by Prof. McIntosh.
6. On the Occurrence of *Lumpenus lampetriformis* off the east coast of Scotland; by Francis Day. Proceedings Zoölogical Society, 1884, p. 445. (1 plate.)
7. Notes from the St. Andrews Marine Laboratory, I. *a.* On the British species of *Cyanea.* *b.* On the Reproduction of *Mytilus edulis.* Prof. McIntosh, Ann. Nat. Hist., Feb., 1885.
8. Notes from the same, II. On the Spawning of certain Marine Fishes (Herring, Vivaparous Blenny, Catfish, Short-spined *Cottus*, Armed Bullhead, Bimaculated Sucker, and Montagu's Sucker); On Pelagic Ova, the Young of the Ling and the Eel. (1 plate.)—Ibid, Ann. Nat. Hist., June, 1885.
9. Lecture on the Ova of Fishes.—Ibid, Nature, April, 1885.
10. The Phosphorescence of Marine Animals, the Presidential Address to the Biological Section of the British Association, Sept., 1885. Ibid.
11. Notes from the St. Andrews Laboratory, III. *a.* On the ova of *Callionymus lyra.* *b.* On a new British *Staurocephalus.* *c.* On certain Processes formed by *Cerapus* on *Tubularia indivisa.* *d.* On certain Peculiar Ova from the Forth. *e.* On a Female Porpoise. (1 plate.) Prof. McIntosh.
12. Note on the Chemical Composition of the Milk of the Porpoise. Prof. Purdie, Ann. Nat. Hist., December, 1885, and Chemical News.
13. On the Development of the Food-Fishes at the St. Andrews Marine Laboratory. E. E. Prince, Rep. Brit. Assoc., 1885, p. 1091.

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*Ninth An. Rept. Fishery Board for Scotland, III, p. 317.

†A. & C. Black, 1875.

14. On the Nest and Development of *Gastrosteus spinachia* at the St. Andrews Marine Laboratory. E. E. Prince, Rep. Brit. Assoc., 1885, 1093; printed in full with 1 plate, Ann. Nat. Hist., Dec., 1885.

14*a* and 15. On the Reproduction of the Common Mussel. John Wilson, Rep. Brit. Assoc., 1885, p. 1094, and Report Fishery Board for Scotland, 1886.

16. On *Golfingia M'Intoshii*, a new *Sipunculus* from the Neighborhood of St. Andrews. Prof. Ray-Lankester, M. A., LL. D., F. R. S., etc., Trans. Lin. Soc., vol. II, part 16. (2 plates.)

17. Notes from the St. Andrews Laboratory, IV. On the Structure of the Tunny. (1 plate.) Prof. McIntosh, Ann. Nat. Hist., April, 1886.

18. On the British Weevers, the Bib, and the Poor Cod. Ibid, Ann. Nat. Hist., May, 1886.

19. Early Stages in the Development of the Food-Fishes. E. E. Prince, Ann. Nat. Hist., May, 1886.

20. Further Remarks on the Tunny. Prof. McIntosh, Ann. Nat. Hist., June, 1886.

21. Remarks on the Eggs of Marine Fishes. Ibid, Nature, 1886.

22. On the Presence of Oleaginous Spheres in the Yolk of Teleostean Ova. E. E. Prince, Ann. Nat. Hist., Aug., 1886.

23. Points in the Development of the Pectoral Fin and Girdle in Teleosteans. E. E. Prince, Rep. Brit. Assoc., 1866, p. 697.

24. Some Remarks on the Egg Membranes of Osseous Fishes. Dr. R. Scharff, Ibid, p. 698.

25. Note on a Peculiar Medusa (*Thaumantias*) from St. Andrews Bay. Prof. McIntosh, Ibid, p. 710.

26. On the structure of the Tail in *Myxine*. Prof. Cleland, M.D., LL.D., F.R.S., Report Fishery Board, 1886, p. 211.

27. Report of the Committee for the Purpose of Continuing the Researches on Food-Fishes and Invertebrates at the St. Andrews Marine Laboratory. Report Brit. Assoc., 1886.

28. Notes from the St. Andrews Marine Laboratory, V. On the Paternal Instincts of *Cyclopterus lumpus*, etc. Prof. McIntosh, Ann. Nat. Hist., Aug., 1886.

29. Notes from the St. Andrews Marine Laboratory, VI. On the very Young Cod and other Food-Fishes. Prof. McIntosh, Ann. Nat. History, Oct., 1886.

30. On some experiments in Preserving Mussels for Bait. Report Fishery Board for 1886 (published 1887).

31. On the Intra-ovarian Eggs of Osseous Fishes. Dr. R. Scharff, Proceed. Roy. Soc., 1887, and Quart. Jour. Micros. Sci., Aug., 1887. (1 plate, 4to.)

32. On the Pelagic Fauna of our Shores in its Relation to the Nourishment of the young Food-Fishes. Prof. McIntosh, Ann. Nat. Hist., Feb., 1887.

33. Notes from the St. Andrews Marine Laboratory, VII. *a*. On the Occurrence of Peculiar Gelatinous Bodies in Profusion. *b*. On *Syncoryne decipiens* Dujardin. *c*. On the Commensalistic Habits of the Larval Forms of *Peachia*. *d*. On the Presence of Swarms of Appendicularians. *e*. On the Occurrence of *Clione borealis*, Pall. Ibid, Ann. Nat. Hist., Aug., 1887.

34. Notes from the St. Andrews Marine Laboratory, VIII. *a*. On a Post-larval *Labrus*, with Remarks on the Color of Pelvic Fins. *b*. On the Post-larval Condition of *Liparis*. *c*. On a Peculiar Teleostean Yolk-sac. *d*. General Remarks on Post-larval Food-fishes. Ibid, Ann. Nat. Hist., Oct., 1887.

35. On some Rare and Remarkable Forms at St. Andrews Marine Laboratory. Prof. McIntosh, Meeting Brit. Assoc., 1887.

36. On the Development of the Ovary and Oviduct in Certain Osseous Fishes. E. E. Prince, Ibid, 1887.

37. On the so-called Luminous Organs of *Maurolicus pennantii*. E. E. Prince, Rep. Brit. Assoc., 1887, p. 769.

38. On the Ova of *Tomopteris onisciformis*, Esch. E. E. Prince, Rep. Brit. Assoc., 1887, p. 769.

39. On the Ciliated Organs of *Tomopteris*. E. E. Prince, Ibid, p. 769.

40. The Emigration of Amœboid Corpuscles in the Starfish. Herbert E. Durham, B. A., lately Vintnor Exhibitioner, King's College, Cambridge, Proceed. Roy. Soc., vol. 43, p. 327 (1 plate).

41. Note on the Madreporite of *Cribrella oculata*. Ibid, Proceed. Roy. Soc., vol. 43, p. 330.

42. On the Reproduction and Development of the Common Mussel. (3 4to. plates). John Wilson, B.SC., Demonstrator of Zoölogy, St. Andrews University, V, Report Fishery Board for Scotland, p. 247, 1887.

43. The Significance of the Yolk in the Eggs of Osseous Fishes. E. E. Prince, Ann. Nat. Hist., July, 1887. (1 plate.)

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44. Further Remarks on the Development and Life-History of the Food-fishes. Sixth Annual Report W. C. M.

45. On Annelids and other Forms used as Bait. Sixth Annual Report.

46. Pelagic and other Fauna of St. Andrews Bay. Sixth Annual Report.

47. Report of the Committee for the purpose of continuing the Researches on Food-Fishes at the St. Andrews Marine Laboratory. Report British Association, 1888.

48. Note on the Bib and the Poor Cod. Ann. Nat. Hist., Oct., 1888.

49. Notes from the St. Andrews Marine Laboratory, No. IX. W. C. M.

    1. On *Lesueuria*, a Ctenophore new to Britain.
    2. On the Development of Mussels.
    3. On a Post-larval Pleuronectid (Sole).
    4. On a Post-larval *Cottus* contrasted with the Gadoids.
    5. On the appearance and disappearance of *Lucernaria* and other Forms. Ann. Nat. Hist., Dec., 1888. Ibid.

50 On the Embryology of the Retina of the Teleosteans. Dr. Marcus Gunn. Ann. Nat. Hist., Sept., 1888.

1889.

51. The Life-History of a Marine Food Fish Illustrated. Lecture to the Royal Institution of Great Britain, Feb., 1889. W. C. M.
52. The Pelagic Fauna of St. Andrews Bay during the months of 1888. (4 plates.) Seventh Annual Report of the Fishery Board, 1889. W. C. M.
53. On the Life-History of the Herring. Ernest W. L. Holt, Ann. Nat. Hist., 1889.

1890.

54. Notes from the St. Andrews Marine Laboratory, No. x. (1 plate.) Ann. Nat. Hist., Jan., 1890. W. C. M.
    1. On Abnormal Hydromedusæ.
    2. On the occurrence of the Ctenophores throughout the year.
    3. On a Heteropod (Atlanta-like form) in British Waters.
55. Notes from the St. Andrews Marine Laboratory, No. xi. Ann. Nat. Hist., April, 1890. Ibid.
    1. On the occurrence of the *Hydromedusæ* and *Scyphomedusæ* throughout the year.
    2. On *Arachnactis*.
56. On the Pelagic Fauna of St. Andrews Bay during the months of 1888. No. ii. Eighth Annual Report, 1890. Ibid.
57. Report on the Pelagic Ova and Young Food Fishes collected by the *Garland*. Ibid, 1890.
58. Notes from the St. Andrews Marine Laboratory, No. xii. Ann. Nat. Hist., Aug., 1890. Ibid.
    1. Preliminary Note on the occurrence of the Pelagic Annelids and Chætognaths in St. Andrews Bay throughout the year. Ibid.
    2. On the British species of *Spinther*.
    3. On the Young Stages of the Gunnel.
59. On the Morphology of the Limbs of Teleosts. Prof. Edward E. Prince, B. A., F. L. S. (4to. 2 plates.)
60. On the Ova of *Gobius*, with plate. E. W. L. Holt, Ann. Nat. Hist., 1890.
61. On the Larvæ of *Zoarces viviparus*. E. W. L. Holt. Ibid, 1890.
62. On the Development of the Brain in *Clupea harengus*. E. W. L. Holt. Proc. Roy. Soc., 1890.
63. On the Development of the Teleostean Brain with special reference to that of *Clupea harengus*. E. W. L. Holt. Sprengels Morph. Jahrbuch, 1890.
64. On the Development and Life-Histories of the Teleostean Food and other Fishes. Prof. McIntosh, F. R. S., and Prof. E. E. Prince, F. L. S. Trans. Roy. Soc. Edin., Feb., 1890. (28 plates. 4to.)

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65. Further Observations on the Life-Histories and Development of the Food and other Fishes. (Plates x–xiii.) Ninth Annual Report Fishery Board for Scotland. W. C. M.
66. Further Note on the *Medusæ* of St. Andrews Bay (Aug., 1890–May, 1891). Rev. J. H. Crawford, F. L. S.
67. On the Occurrence of *Halistemma* in British Waters (St. Andrews Bay). Rev. A. D. Sloan, M. A., B. SC., Ann. Nat. Hist.
68. Some Features in the Eggs and Larva of the Skulpin. Prof. Prince, Ninth Annual Report Fishery Board for Scotland.
69. Further Observation on the *Hydromedusæ* of St. Andrews Bay. Rev. J. H. Crawford, Ann. Nat. Hist.

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70. Additional Observations on the Development and Life-Histories of the Marine Food-Fishes and the Distribution of their Ova. Proc. Roy. Soc. Edin., Feb., 1892.
71. Contributions to the Life-Histories and Development of the Food and other Fishes. (Plates xiv–xvii.) Tenth Annual Report, 1892, Scotch Fishery Board. W. C. M.
72. Notes from the St. Andrews Marine Laboratory, No. xiii. Ann. Nat. Hist., July 1892. Ibid
    1. On the Eggs and Young Stages of the Sand Eels.
    2. On the Ova and Larvæ of certain Pleuronectids.
    3. On the Atlanta-like larval Mollusk.
73. A Brief Sketch of the Scottish Fisheries, chiefly in their Scientific Aspects, during the past decade, 1882–1892. Nov., 1892. Ibid.
74. On the Preservation of Teleostean Ova. W. E. Collinge, St. Andrews Marine Laboratory, Ann. Nat. Hist., Sept., 1892.

28.—DESCRIPTION OF THE MARINE HATCHERY AT DUNBAR, SCOTLAND.

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In a paper by Prof. W. C. McIntosh, included in the present Bulletin (pp. 241–256), reference is made to an establishment for hatching marine food-fishes at Dunbar, which has been erected by the Fishery Board for Scotland, and of which I have been asked to furnish a description. It may be briefly premised that in Scotland, as in so many other countries, the comparative scarcity of certain important sea fishes has been manifested in recent years. This has been especially evident with the more valuable *Pleuronectidæ*, such as turbot, brill, and plaice. Notwithstanding the extension of beam-trawling—the method of fishing by which the pleuronectids are principally obtained—the number captured off the Scottish coasts has diminished year by year; as indeed they have diminished throughout the North Sea generally.

Certain regulative measures have been tried, which, if it can not be said they have quite failed, have at least not had the results they were expected to have. In 1886 and subsequent years beam-trawling was prohibited within certain firths and areas; and in 1889 practically the whole of the territorial waters of Scotland, and also some bays and firths which extended beyond the territorial limit, were closed by statute to this mode of fishing. But the quantity of flatfishes landed continues to decrease. That this is not due to restriction in the extent of fishing ground in consequence of the prohibition referred to, is shown by the scientific observations and experiments conducted by the *Garland* since 1886. These are given in full detail in the various annual reports of the Fishery Board; but it may be mentioned here that while in the period 1886–1888 the average number of flatfishes captured in each haul of the net in the protected waters of the Firth of Forth and St. Andrews Bay was 188·6, it was only 136·4 in the period 1890–1892. The diminution indicated is probably largely explained by increased trawling in the waters outside the territorial zone where the fishes congregate at the spawning season and where fishing operations can not be interfered with under any powers at present existing. At all events it shows that the regulative measures referred to have not succeeded in increasing the abundance of fish in the protected waters, and points to a hopeful field for the application of fish-hatching.

When it was decided to proceed with the erection of a hatchery for sea fish, the writer visited and inspected the well-known Norwegian establishment at Flöderig, which is under the direction of Capt. G. M. Dannevig; and later this gentleman came to Scotland and made an examination of the site proposed at Dunbar. He having reported favorably, work was thereafter commenced, and a hatchery on the model of

Capt. Dannevig's has now been completed. The establishment may be described under the following heads: (1) the hatchery house; (2) the spawning pond; (3) the filtering gallery; (4) the tidal pond; (5) the pumping apparatus.

The hatching house consists of a substantial and ornamental wooden building 35 feet in length, 24 feet broad, and 18 feet in height. The walls, which are double, stand upon a foundation of brick and concrete, a space of 2 feet being left between the flooring and the ground for the circulation of air and the convenience of piping. As abundance of light is desirable, there are 12 large windows in the sides and gables and a door is placed at either end. At present 16 of Dannevig's hatching apparatus are fitted up, each capable of containing about 5,000,000 of cod eggs, or a total of about 80,000,000.

The apparatus consists of an oblong wooden box, 8 feet in length, 2 feet 3 inches in breadth, and 1 foot deep. It is divided into two series of 7 water-tight compartments by one central longitudinal and 6 transverse partitions, making altogether 14 compartments. The first and last compartments in each series—those at the ends—are narrow and communicate with one another, the pair at one end receiving the water from the inflow pipe, and the pair at the other end communicating with the outflow pipe. The intervening ten compartments are wider, and it is into these that the hatching boxes which contain the eggs are placed.

Each hatching box is 12 inches long, 10 inches broad and 10 inches deep; the sides are made of wood, ⅝ inch thick, and the bottom of haircloth, fine enough to prevent any eggs from passing out while admitting a free circulation of water. The boxes are attached by leather hinges to the transverse partitions; and into the top of each partition, between the hinges, a broad, flattened metallic spout is inserted, which fits into a corresponding spout attached below it to the edge of the hatching box. The apparatus, with its ten boxes, is placed with one end against the end of the room, and rests on wooden supports so arranged that this end is 3 inches higher than the end which projects towards the center of the room, this difference in level giving what experience has shown to be the most suitable flow of water.

The supply pipes, made of galvanized iron, are led along the walls, a brass cock being inserted above each apparatus. The water falls from the cock into one of the narrow end compartments, which communicate with one another, and when these are full it flows over by the spouts into the first pair of hatching boxes. It passes through the haircloth bottom into the compartments in which the boxes are placed, and when these are full it overflows in turn into the second pair of boxes, and so on until it reaches the narrow end compartments, whence it escapes by a pipe passing through the floor of the room.

As has been said, the hatching boxes are hinged at one side, and as the compartment becomes full the fore edge of the box is floated up and ultimately projects about 3 inches or so above the surface. This gives occasion for the application of one of the special features of Dannevig's method, namely, an up-and-down movement of the box, by means of which the eggs are kept equally distributed throughout the mass of water, as may be shown by testing any part of the box with a dip-tube. The movement is accomplished in the following way: An iron rod, 8 feet long, is hinged at the upper end of the apparatus, next the wall, and passes down the middle between the two series of hatching boxes. It possesses five short, transverse pieces, one opposite each pair of boxes, and resting upon the free edges of the latter; and it is so weighted as just to be sufficiently heavy to depress them. When the rod is raised the buoyancy of the boxes causes them to rise and to regain their former position.

The movement of the rods is brought about automatically by a system of wires and pulleys, the wires being connected on the one hand with the free end of the rods, and on the other hand with the end of a wooden beam which rests upon an eccentric wheel kept in motion by a waterwheel driven by the overflow water from the spawning pond. As the end of the beam rises and falls on the eccentric the iron rods also rise and fall, and the hatching boxes are raised and depressed. The rise is gradual and the depression rapid, the water in the latter part of the movement being forced upwards through the hair netting and the eggs whirled gently about and kept in constant motion. The speed of the eccentric wheel can easily be regulated; about two revolutions in three minutes is generally sufficient.

The spawning pond or tank, in which the spawning fishes are placed during hatching operations, is constructed of solid concrete sunk in the ground, the thickness of the walls at the top varying from 2 to 4 feet. It is 40 feet in length by 11½ feet deep, the breadth at one end being 26 feet and at the other end 18 feet, the variation in breadth being due to the nature of the ground. It is capable of containing a little over 60,000 gallons of water. This pond is situated 27 feet from the hatching house, and on higher ground, so that the level of the water in it is about 18 feet above the level of the hatching boxes, and it is inclosed by wooden walls which rest upon the outer edge of the concrete, and is covered by a roofing of galvanized iron with movable skylight windows, which can be darkened when necessary. The upper flat surface of the concrete forms a convenient pathway all round the pond.

The feed pipe from the pumps is carried along the top and enters at one corner (that furthest from the overflow into the spawn-collector), and it is so arranged that the water can be put in at any height. In order to empty the pond, or lower the level of the water, two 4-inch iron pipes pass through the bottom, each controlled by a cock worked from above by a fixed rod, and communicating outside with the waste and drain pipes, and inside with a series of movable perforated pipes lying on the concrete floor, and by means of which the bottom layer of water can be rapidly removed. About 18 inches above the bottom is a flooring of smooth boarding, with spaces between, the width of which may be increased or diminished according to circumstances. The object of this arrangement is to allow excrementitious waters, remains of food, etc., to pass beneath the flooring, whence they may be quickly taken away by the perforated pipes. Three 2½-inch galvanized iron pipes are also carried through the wall at different levels and pass into the filtering gallery; they are provided with cocks, and their use will be presently explained.

It is into this pond that the spawning fishes, males and females, are placed, and the spawning process, the ejection and impregnation of the eggs, goes on naturally as it would in the sea. As the buoyant eggs rise to the surface they are carried by the overflow into the "spawn-collector." The eggs are retained, and the water passes on into the chute to supply the waterwheel for the movement of the boxes, as above described. The spawn-collector consists essentially of a large wooden frame, the bottom, sides, and one end of which are covered with haircloth. It is placed in a large horizontal wooden box, which may be described as a dilatation of the water-chute to the wheel with which it communicates. This box is deeper and wider than the haircloth frame, so that a space may exist all around the latter; and it is continuous with a short chute passing between the spawning pond and the open end of the spawn-collector. All the overflow water must pass through the haircloth, and by means of wooden slides the height and flow of the water may be regulated so that the retained eggs may not be subjected to injurious pressure. The eggs are transferred from the collector to the hatching boxes.

The filtering gallery passes down the sloping bank between the spawning pond and the hatching house. The floor is made of concrete, and a stair passes up the center to the spawning house. On either side are arranged the filtering boxes, eight in number, forming a duplicate series of four each, and through these four filters all the water that goes to the hatching boxes must pass. Each filtering-box is 4 feet long, 2 feet wide, and 1½ feet deep. The top is covered by a movable frame of filtering material, made in two pieces for convenience of removal; and as the boxes are arranged at different levels, in step-and-stair fashion, the water passes in succession from the first to the second, and so on to the fourth, and thence to the pipe leading to the hatching boxes. The filtering material on the first box is made of coarse material (cheese cloth); that on the second, coarse flannel; finer flannel on the third, and still finer on the fourth; but, as a rule, no sediment is to be found on this one, and the water passing to the hatching house is absolutely limpid and pure. One object in having a duplicate series, which can be used alternately or together, is for convenience in cleaning. There is also a wooden sink, supplied with water from the waterwheel shoot, in which the filtering frames may be scrubbed.

The spawn-collector, above described, is contained in the upper part of the gallery, and the shoot to the waterwheel passes down one side, near the roof. The waterwheel is placed at the side of the hatching house, at the lower part of the gallery. It is 5 feet in diameter, of the overshot variety, and the axle passes through the wall of the hatching house, the movement being transferred to the eccentric wheel by a stop. From 700 to 900 gallons of water an hour is sufficient to supply the wheel, the waste water being carried off by a drain pipe.

The *tidal pond* is situated about 50 yards from the hatchery, on the rocky shore. It was originally a cavern,* the walls and roof being of solid rock, and the eastern part closed by the castle walls. The seaward entrance has been closed up by a concrete wall varying in thickness from 9 feet to 2 feet. Through this wall two 6-inch pipes are carried, one at the bottom which is controlled by a slide valve worked by a rod from above; the other at a height of 5 feet. The valve in connection with the latter is such that it can work automatically, admitting water when the level outside is higher than that within, and preventing water from escaping when it is lower. The bottom pipe is for emptying, or partly emptying the pond when the tide is low. Thus at every tide a fresh supply of water may be admitted if desired. Both pipes open on the inner side into a long, vertical water-tight wooden box, which fits against the concrete wall, and is open above so that the valve may be controlled. Large filtering frames are fitted into apertures in this box by india-rubber joints, so that practically every drop of water entering the pond may be passed through them—a very useful provision in stormy weather.

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*It may be of interest to state that the hatchery lies within the precincts of one of the most historic spots in Scotland—the old castle of Dunbar—associated with Scottish history for 800 years, and dismantled subsequent to the flight of Queen Mary and Bothwell, who took refuge in it. A human skull and a large quantity of the bones of horses were disinterred in digging the foundations for the spawning pond. A portion of the cavern, now converted into a peaceful fish-pond, formed the dungeon in which the poet Gavin Douglas, Bishop of Dunkeld, and many other illustrious prisoners were confined. A dark and tortuous passage still exists, leading upward between massive walls towards the citadel. The westward opening, now closed, is conjectured to have been the portal through which the brave Sir Alexander Ramsay, of Dalhousie brought succor to Black Agnes during the siege of the castle by the English under the Earls of Salisbury and Arundel in 1338, and it was probably by this postern that King Edward II escaped in a fishing boat after his disastrous defeat at Bannockburn in 1314.

At the end opposite to the concrete wall is a stone-work platform continuous with the harbor quay, and a door is let into the wall, at this part of which entrance to the pond is obtained. The length of the pond is 42 feet, the average breadth about 20 feet, and the depth of water at high tide about 9 feet; it can therefore contain nearly 50,000 gallons of water—all of which, as has been explained, filters itself as it passes in. The bottom is laid with concrete, and when fish are present this is covered with a layer of clean sand. The purpose of the tidal pond is twofold: (1) it serves as a storage place for the spawners, in which they may be collected before the spawning season, and (2) as a reservoir of pure filtered water which may be pumped up to the hatching house during the prevalence of storms, when the water outside may become somewhat turbid in certain winds. As the tide rises the water pours in by the upper pipe and passes through the filtering apparatus into the pond; when the tide falls, the valve closes automatically and prevents the escape of the water.

The pumping apparatus consists of two Worthington brass-lined, direct-acting steam pumps, each capable of throwing over 3,000 gallons per hour. The boiler is of the best locomotive type, made of steel, by Robey & Co., Lincoln, and of 8-horse power. The pump house is placed between the hatchery and spawning pond on the one hand, and the harbor and tidal pond on the other hand. It is 24 feet long by 18 feet in breadth. The floor is of concrete, and a partition separates the boiler from the pumps. Built against the boiler compartment is the coal house, which can accommodate about 12 tons of coal. The pumps are so fitted up that one may pump from the entrance to the harbor, and the other from the tidal pond, or one or both may pump from the harbor and the pond at the same time. The suction pipes are 2½ inches in diameter, and made of the best galvanized iron; they are supplied with foot-valves and roses. The supply pipe to the spawning pond and hatchery is of the same diameter and material. At the side of the spawning pond a branch is given off to the filtering-gallery, and this branch on entering the gallery bifurcates to supply each of the two series of filtering-boxes. Cocks are placed so that the volume of water entering the spawning-pond or the filtering gallery can be easily regulated. The Worthington pumps have worked very smoothly, without any noise, and have given satisfaction.

There is a special feature in connection with the working of this hatchery to which attention may be drawn. At the Norwegian establishment and, I understand, at others, the pumps are kept working during the night as well as in the day, so that a constant supply of water may be obtained for the spawning pond and the hatching boxes; this, of course, necessitates extra staff and expense. At the Dunbar hatchery, however, the night work is dispensed with, water from the spawning ponds being used for the hatching boxes and the waterwheel, by means of the three pipes, previously referred to, which pass through the wall of the pond. These pipes are fitted on the inner end, which projects into the pond, with large haircloth roses or filters, which prevent any eggs passing out with the water. One of these is connected in the gallery house with the pipes supplying the filtering boxes, and another is led into the lower part of the shoot for the waterwheel. By means of the cocks, the supply of water for both these purposes can be easily regulated.

Since each of the sixteen hatching boxes requires between 90 and 100 gallons of water per hour, and the waterwheel about 800 gallons; and since each inch of depth in the pond is equivalent to about 480 gallons, the utilization of the water in this manner from 11 o'clock at night to about 6 in the morning will reduce the level of the water in the pond to the extent of only about 2½ to 3 feet. This can soon be made up when the pumps are put on. The fish at present used—plaice—do not require a constant circulation to be maintained; indeed, in some preliminary operations in the tidal pond it was found that eighty large flatfish (including a few common soles) could be kept for two days and three nights in about 7,000 gallons of water, in perfect health, without the water being renewed or any circulation maintained. It would be probably different with more actively-breathing fish, such as cod.

Another advantage of retaining the water in the spawning pond during night is that the impregnation of all the eggs is made more certain and with a relatively smaller number of males than would be the case were a constant overflow kept up. Spawning takes place at night and the eggs are confined floating in the pond for many hours. In the morning the pumps are started, and a very gentle circulation maintained during the day; in the afternoon a large volume of water is poured in, and in the course of a few hours practically all the eggs in the pond are collected in the spawn-collector.

The number of plaice at present in the spawning pond is 220, ranging in length from 14 to 27 inches; but they are being added to, it being estimated that the pond can accommodate more than double the number named. There are two males to three females, this being the proportion of the sexes which obtains in the sea;* but it is probable that the proportion of females may be considerably increased (and therefore the functional capacity of the pond), owing to the special facilities for impregnation adverted to above.

The hatchery has been in operation only for a few weeks, and, so far, with the greatest success. The death rate among the eggs has been exceedingly small, far below what is usual with cod eggs. Mr. Harold Dannevig has charge of the hatching operations, and to his systematic attention much of the success is due. It is hoped, later in the season, to proceed with the hatching of the common sole, lemon sole, and possibly the turbot; and it should be stated that the present plant—boiler, pumps, ponds, waterwheel, etc. — is sufficient for a hatchery double the size of the one existing, *i. e.*, for between 30 and 40 of Dannevig's apparatus.

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* *Vide* a paper by the writer on The Reproduction, Maturity, and Sexual Relations of the Food Fishes: Tenth Annual Report Fishery Board for Scotland, part III, p. 239. 1892.

29.—THE PAST, PRESENT, AND FUTURE OF THE OYSTER INDUSTRY OF GEORGIA.

BY A. OEMLER, M. D.

We have but one species of oyster (*Ostrea virginiana*) on the coast of Georgia, but the shape and quality varies with the food and with the conditions which surround each individual. When found in large masses above ordinary low-water mark, bordering the marshes of rivers and creeks, it assumes the "coon" or "razor-blade" type, growing vertically, long, thin, and very sharp, like trees too crowded in a forest; a veritable illustration of a contest for the survival of the fittest. The usual width of these coon oyster ledges is from 8 to 10 feet, but the nearer to the sea we find them, or the greater the salinity of the water, the broader they become, reaching in some cases near the line of ordinary high water. As further consequences of the higher density, the oysters remain of poor quality later in the season, not improving in dry seasons until November, and spawning later than those situated in water of a lower degree, or approaching the standard of 1·0140, and better adapted to the American oyster, which is strictly a brackish-water mollusk. The density of the water over the ledges in the lower creeks and rivers in South Carolina ranges between 1·0214 and 1·0250.

Not being constantly submerged the deposit of mud on these coon oysters is slight, and that is removed by the action of sun and wind, hence they form clean collectors for an annually heavy set, producing a very crowded condition of living oysters with no room to grow laterally. When, however, a full set occurs on a planted, clean shell, the development is in all directions, the cluster sometimes breaking apart from the pressure of its own growth, and the shape and quality is better. Finally when a spat or two finds lodgment on a small object, or on a partially clean shell, we have the ideal single oyster to be enjoyed on the half shell. If oysters drop from these coon ledges near the sea into the stream below the line of low water, they usually perish, hence we find here no rocks or beds of oysters in mid rivers or creeks; but when this occurs from ledges not in so close proximity to the ocean, these "dropped off" oysters improve in form and quality, and here beds occur beyond the shore sustained by annual sets. The drill (*Urosalpinx cinerea*), the only enemy of the coon oyster in our waters, is found in these locations with greatest density, but not in such numbers as to account for the destruction. This difference in the life-history of specimens of the same species is evidently attributable to the difference in density, the American oyster not being able to survive and prosper in water of great salinity.

From my earliest childhood, I can remember the great abundance of oysters in Chatham County, and one of my earliest memories is, seeing my grandfather, a Revolutionary patriot, eating roasted oysters and sweet potatoes at my present home on Wilmington Island. With the exception of ten years in Germany, I have resided here, off and on, for sixty years, and constantly for the past twenty-seven years, near to what were formerly the finest and most productive oyster-grounds in the State of Georgia, and have been able to observe their rapid exhaustion, and thus have feared their impending total extinction through improvident fishing. Fifty years ago, when the city of Savannah had a population of about 13,000, and there was no outside demand, the market was readily supplied, without any necessity to resort to tongs or any other implement, and even when ten years later shipments into the interior began to be made, they were rarely employed.

The shores of the larger creeks, and of the rivers in favorable locations above low-water mark in Chatham and Bryan counties, were lined with "coon oysters," which supplied the stock for opened or shucked oysters. The bottoms of high-water creeks, or such as went dry or nearly so, under favorable circumstances were more or less covered with single oysters, which were gathered by "picking." Sometimes the finest specimens were procured by hand, about a foot deep. This method required no culling, and had the great advantage of involving no disturbance of the empty shells.

Population having increased and the demand having become greater the beds both above and below low-water mark had commenced to deteriorate, when the enforced rest during the period of the civil war restored them to a greater degree of productiveness. The period of most rapid depletion of the grounds of Chatham and Bryan counties, which had formerly supplied the trade of Savannah, is therefore embraced within the last twenty-seven years. Three years ago all the ledges and banks of coon oysters, other than those at private landings, being in sight and easy of access, had completely disappeared, and the natural beds below low-water mark had decreased in productiveness fully 87½ per cent. The culls of tonged oysters are now used for opening, and for the several years past the trade has had to be supplied from the southern counties and from the less-ravaged beds in South Carolina. In 1886 my sons shipped 1,546 barrels of shell oysters to Philadelphia, but during the next season they were only able to procure 881 barrels with nearly double the number of tongers. About ten years ago I applied to the agent of the Ocean Steamship Company for space in the ship's ice box to send a 2-gallon can of opened oysters as an experiment to New York. He replied it was like sending coals to Newcastle; but since then the trade has greatly increased; a single party who visits Savannah every season for the purpose ships about 13,000 gallons, mostly to Boston, Mass. He has never been able to procure more than half the quantity wanted during the months of November, December, January, and February, and the supply has been decreasing annually.

Ensign Drake, in Bulletin No. 19 of the Coast and Geodetic Survey, estimates the total area of the public oyster beds at 1,700 acres, and even if he had included the few exhausted beds, which he intentionally omitted in his delineations, it would still be inconsiderable. According to the somewhat incomplete survey, South Carolina has 773 acres, nearly exclusively coon oysters. Lieut. Francis Winslow reports 10,165 acres in North Carolina, and the oyster commission of Maryland, in their report of 1884, quote 123,520 acres in that State. To have maintained our beds in any satisfactory state of productiveness as public oyster beds, would have required the exercise of a high degree of intelligence and the most vigilant care from the start, instead of which they have been constantly ravaged by the most outrageous improvidence of their privileged destroyers, and but for the fact of usually an annual set in our climate, they would have been exterminated in a much shorter period.

The colored oystermen (there is not a single white man now engaged in the precarious occupation of tonging oysters in Chatham County, although a few had assisted in the process of depletion) fill their boats during the last quarter of the ebb tide and the first quarter of the flood, indiscriminately with oysters, loose shells, and other débris of the beds, and while drifting homewards they cull their loads. All the young oysters, of the most recent set, and all the empty shells, so indispensable as collectors to replenish the beds, are thrown overboard to be engulfed in the soft mud of the river bottom, or when the culling process has not been completed in transit, they are as effectually destroyed by being cast upon the shell heap at home. Thus, the oyster beds are bodily removed; the elevations, which had prevented the deposit of silt, are reduced to the general level, and an area which might give employment and sustenance to their descendants vanishes forever as a source of food for the public.

That community or State enjoys the greatest degree of prosperity which encourages private enterprise, enhances production, and increases its exports; hence any treatment of the natural oyster beds (belonging to no class of individuals, but to the people at large of the State) which could restore them to their former condition or would increase their yield a thousandfold could not fail to give more employment to labor and promote the public welfare.

Being an eye-witness to the rapid march of our beds to the usual fate of extermination; believing in the correctness of the Malthusian theory that the population increases in a geometrical ratio while the production of food can only increase in an arithmetical ratio, when all the arable land is cultivated and when all other sources of food are developed by the application of intelligence and enterprise; and desiring to provide every oysterman with an oyster farm of his own, upon which he could at least save his enormous waste for future use, I commenced an agitation in 1887 for a more enlightened, more progressive, and more protective oyster law. The old law of 1876 only restricted the oystermen to the use of the tongs previously in common use, and secured riparian rights and the privilege of planting oysters opposite their habitable highlands to the land-owners to the distance of 120 feet below low-water mark.

In order to inform the people of the merits of the case, I addressed several communications to the public through the medium of the daily press and delivered a lecture on the "Life-history, propagation, and protection of the American oyster" at the two monthly meetings of March and April, 1889, of the Georgia Historical Society. Subsequently a printed copy was distributed to each member of the two houses of the Georgia legislature, at the sessions of 1889 and 1891. As usual with every reform, I encountered violent opposition. The dealers in Savannah were the principal opponents. The public were informed that the clause providing for a close season was an interference with a free trade in oysters. I quote from one of the contributions:

> The returning of the shells to the banks is rather a ridiculous and uncanny undertaking, as there are always enough shells left there to furnish resting-places for all the loose spawn that may be floating around, and, besides, it is not an uncommon thing for it to take root in the mud, which the doctor claims is such a merciless enemy to the young oyster. The oysters do not need any protection; there are thousands of beds on the Georgia coast that have never been molested, and thousands of beds being formed every year.

Whereas, in fact, we have not a single record of the formation of a natural bed, and know that a whole century is not a sufficient period. One legislator from the coast stated if my bill became a law the governor would be compelled to call out the militia to suppress riot among the oystermen. However, after being amended, it passed the house without a dissenting vote, and was signed by Governor Gordon in September, 1889. The most important feature of my bill, which failed of passage, provided for a salaried oyster inspector for each three of the six coast counties. No game, fish, or oyster law can ever be properly enforced without such a responsible officer. One of their duties might have been the enforcement of the law for the protection of terrapin, which I had framed, advocated, and was instrumental in getting previously passed some years before by the Georgia legislature. The appointment of these officers would have obviated subsequent litigation by supplying a very effective witness in every case of oyster piracy, and would have been a valuable aid to the county commissioners when called upon to grant leases in strict conformity to the law.

The legislature provided, at the same time, principally at the instance of the opposition, but in accordance with the desires of the friends of the oyster industry, for the appointment of three oyster commissioners for the purpose of investigating what further legislation should be recommended at the next ensuing session to perfect the law, and Governor Gordon appointed J. L. Warren of Savannah, R. W. Grubb of Darien, and James Postell of Brunswick. After an interview with Governor Gordon I wrote a resolution, which was presented by Hon. James Postell to the legislature and passed, and then, upon application to the U. S. Government by the governor for the purpose, Ensign J. C. Drake, the most available expert, was detailed to make a survey of the oyster grounds and waters of Georgia. His report was issued as Bulletin No. 19 of the Coast and Geodetic Survey.

The most important features of the law were: (1) A close time from May 1 to September 1; (2) the culling of oysters over the beds; (3) the carrying of lights in boats employed in tonging at night; (4) the leasing by the county commissioners of 5 acres, and no more, at $1 per acre, for the term of twenty years, within 1,000 feet from shore, not to extend beyond the center of the stream, and the ground was not to have been previously resorted to by the public to procure oysters for consumption or sale, and these leases were not transferable; (5) the leasing on similar terms and restrictions of 500 acres in mid-stream, or beyond 1,000 feet from either shore. No lessee could take up ground within 120 feet from low-water mark opposite habitable highlands. The rental in all cases went into the school fund, and the land had to be returned for taxation.

Under the provisions and protection of this law, four oyster companies, three with canning outfits and each with considerable capital, were promptly organized. Each of the three employed nearly as much labor as Ernest Ingersoll reported in the Tenth Census of 1880, the entire number of the planters, tongers, and wholesale dealers engaged in the industry of the State being 300 and the estimate of the value of all the shore property being $5,000.

In Chatham County the Oemler Oyster Company took up 357 acres in Wilmington River beyond the 1,000-foot limit and secured 300 acres in 5-acre lots. These latter being nearly all opposite the habitable highland of Wilmington Island, were not nearer than 120 feet from ordinary low-water mark. Private oystermen, white and colored, took up about all the bare bottom in shallow water fit for oyster culture, not aggregating 100 acres. Larger areas were taken up in Glynn and in Camden counties.

When Ensign Drake first appeared with the U. S. schooner *Ready* in our waters he had several native oystermen to locate on his chart all the natural beds known to them, whether depleted or otherwise, and I do not believe a single one was overlooked in Chatham County, not as an aid merely in his work, but in order to learn what were claimed by the people as public oyster beds. During the progress of his survey he found areas so claimed, and to my own knowledge so indicated, to be virtually valueless as public beds, and, therefore, omitted them in his delineations, believing they would become of more benefit to the public if taken up, cultivated, and made productive. In his report he refers to two such cases specifically, as follows:

> A few natural beds were found in this river (Wilmington) principally between Thunderbolt and Turner Creek, but they are of no consequence, having been about exterminated by excessive fishing, being so near the oyster market. * * * Very few oysters are now found in Oyster Creek, but they are of fine quality. There are a few scattered oysters and dead shells over the upper half of the creek, but they have not been considered thick enough to be indicated on the chart.

Now, although such territory was not subject to lease under the law of 1889 and very well known to have been natural beds, leases were granted here in violation of the law, and in the lower counties large areas were leased, actually indicated on the charts of Bulletin No. 19 as natural beds. In cases before the courts for trespass, the defendants and their witnesses might swear, and have sworn, that barren ground which had been leased and cultivated by a colored man had been a natural bed, and negative facts are difficult of proof. In one such case I had myself prepared the application for a colored oysterman (gratuitously) and made affidavit before the county commissioners about the barrenness of the bottom. In order to prevent further encroachments on the productive grounds, so necessary for a public supply, at least until the leaseholds could become productive; in order to supply absolute proof of the presence, under the law, of a public bed, and thus to diminish or prevent litigation and piracy, and, also, in order to increase the very small area fit for oyster-culture in shallow water, the oyster commissioners recommended that Bulletin No. 19 should be legalized as conclusive evidence of the location of the natural beds, all vacant grounds on the charts to be leasable. This now met the views of the two largest country dealers, who each own several sloops and schooners for the gathering of oysters for the city trade, who have more capital invested than the city dealers and who desired to become oyster cultivators.

The other most important features recommended by the commissioners were the transfer of leases, and that lessees of 500 acres should be permitted to supplement their areas by inshore territory when they were unable to find the full acreage in mid-stream. A bill was prepared by myself in strict conformity with the recommendations of the commissioners, and it passed both houses of the legislature without opposition. An attempt was made to induce the governor to withhold his signature, and subsequently to amend the law and make Bulletin No. 19 only prima-facie evidence, but both fortunately failed. In reference to the mode, policy, or benefits of preserving the exhausted beds for the support of future generations, Prof. W. K. Brooks, our greatest authority upon the oyster, wrote me:

> The only way I see to restore and maintain exhausted beds is by cultivation, for, even if a few of them should recover under natural conditions, they would again be destroyed as soon as they are opened again to the public.

Ensign Drake, in a letter from Yokohama, Japan, November 16, 1891, wrote:

> For the good of the State and its *useful* citizens I would have curtailed the delineations of the natural beds far more than in Bulletin No. 19, had I known that the legislature might adopt the report as legal evidence of public oyster-grounds.

In Bulletin No. 19 Ensign Drake says of Wilmington River:

> It is believed that oysters can be grown successfully in the major portion of this river, especially in the deep and harder bottom from Turner's Rocks to the mouth.

Mr. H. J. Lewis, an extensive and experienced oyster-culturist of New Haven, Conn., and president of the Oyster Cultivation and Canning Company, of Brunswick, Ga., dredged this river carefully with a view to taking it up, actually began negotiations to that end, and pronounced it the best river in Georgia. Its depth of from 20 to 35 feet was not considered objectionable, in view of the fact that some of the best grounds in Long Island Sound have 14 fathoms over them.

In March, 1890, the Oemler Oyster Company planted 11,520 bushels of oysters on the upper end of its territory in deepest water of midstream, which the expert, Ensign Drake, had pronounced the most promising; and partly along shore in close proximity, and partly near the middle of the river, the depth ranging from 20 to 35 feet, it put down in May 18,500 bushels of shells. On the shore area spawners were distributed with the shells. At the first examination the oysters were found to be perishing, and in a few months hardly a living specimen could be discovered, yet not a starfish nor drill had appeared, nor did the oysters suffer for food.

The company then discarded all its midstream grounds, but planted, between November, 1890, and April, 1891, 111,158 bushels within the 1,000 feet limit, opposite Wilmington Island and opposite and below Skidaway Island, a portion being virtually over 2 miles from any habitable highland. These were examined several times and always seemed promising. When they had been down about sixteen months 400 bushels were dredged up in the presence of the directors, myself being one of them, from different portions of the ground for the purpose of determining whether we would utilize them at once for canning or not. They seemed to be still prosperous and came up perfectly free from silt; in fact all the oysters on the lower surface of large heavy bunches, upon which they had rested, were as sound as any, indicative of a very hard bottom, free of silt or sand. The superintendent of the company wished to use some of them, but the board unanimously voted they should remain longer for the anticipated improvement in growth and condition, and in the meantime we would depend upon other sources. Two very small starfish were found on this occasion near the lowest part of the ground. When, eight months later, we proceeded to dredge them, so many had perished that the entire planting of 123,500 bushels had to be considered a total loss, as it would not pay to take up the survivors with the much greater mass of dead oysters. Thus, instead of an increase of at least 50 per cent in two years, or about 200,000 bushels, the company got virtually nothing. Full-grown starfish were now found, but still exclusively on the lowest end of the territory, and their presence could not account for the death of the oysters.

On the other hand, the company planted 55,311 bushels of oysters in the spring of 1892, and 16,500 bushels of shells in May, 1892, on a part of its 180 acres in the shallower and fresher waters of Oyster Creek, the latter being about and above low-water mark. The depth of the creek nowhere exceeds 15 feet. The shells put down here, and elswhere, in shallow water in 1891 and 1892, of high or low density, secured an astonishing set, and if left undisturbed would have supplied nuclei for coon-oyster ledges in both densities alike. When recently examined the oysters seemed in a prosperous condition. At the time the first shells were deposited I was aware of the failure at Brunswick, the year previous, to secure a set in deep water, and subsequently learned that the absence of a set in the deep waters of the south was being investigated by the U. S. Fish Commission. My opinion, therefore, is that the deficient set, the death of the spat, and the destruction of mature oysters in Wilmington River, at

Brunswick and elsewhere, is attributable to the salinity of the water, and that the American oyster can not endure constant submersion in water of great density at the South, and that the mere specific gravity does not affect the set. The theories advanced explaining the absence of a set in deep water at the South are as follows:

1. The extreme density of the water preventing the swimming embryos from sinking at the fixative stage.
2. The extreme softness and film-covered character of the bottom preventing the oyster from fixing.
3. The suspension of slowly depositing silt in the deeper water, whose clogging action is fatal to the delicate respiration of the microscopic young.
4. Changes in the composition of the oyster-bed water, either in its salts or food constituents, at different levels.

Dr. Bashford Dean remarks in "The Physical and Biological Characteristics of the Natural Oyster Grounds of South Carolina" that "if the first theory be correct, spat in no instance should be found in deep water of high specific gravity," and that "spat has been sparingly found affixed to deep-water shells, but we must admit that it may have been attached before the host itself dropped into deeper water."

When the shells we had planted in water not anywhere less than 20 feet deep were examined, a slight set had undoubtedly occurred, and but for the exceedingly warm winter and early spring, which induced the mother oysters to emit their spawn very early, it would have been heavier. In fact, we first attributed our failure entirely to this fact. But in every instance the young oysters, all less than one-eighth of an inch in diameter, were dead. The upper shells were intact, but could be brushed off by the slightest touch. Previous fixation could not have occurred in our case, for all the shells were 8 or 10 years old, and time and rough handling must have removed all such young oysters before the shells were deposited. If a set occurs at the North in consequence merely of the ability of the spawn to sink at its fixative stage, and does not do so at the South in water of exactly the same specific gravity, then the inevitable conclusion follows that the spawn of all northern oysters is heavier than that of all southern oysters of the same species.

Dr. Dean also says that as the water becomes fresher the oysters, with spat of undeniably recent attachment, as in the North, should be found in favorable localities covering the bottom; and, accordingly, as the water becomes less salt the raccoon ledges should gradually and entirely disappear. He says:

> This does not maintain. Notwithstanding the water becomes fresher in character, deep beds of single oysters do not become common in an increasing ratio. Such as are found rarely have spat attached, and in every way appear still to represent the dropped-off raccoons. As the water becomes less dense raccoon ledges do not disappear. Oyster ledges occur in Winyaw Bay, where the specific gravity of the water is as low as 1·010.

Now, as has been stated, coon oysters dropped from the ledges and constantly submerged in water of high density perish, and while there does not seem to be any reason why coon ledges should not be able to form in water of low density under favorable circumstances of freedom from silt and the presence of collectors on the shore, the fact is undeniable that they do generally diminish as the water becomes fresher in rivers receiving a large amount of fresh water, and that the oysters improve in quality as the density declines. This obtains in the rivers of Georgia, and natural beds independent of coon reinforcement have remained self-sustaining in the fresher waters from generation to generation for centuries. This fact is perhaps more evident in Chatham County, receiving the waters of the Savannah and Ogeechee rivers, than elsewhere. Of the 384·7 acres surveyed and reported by Ensign Drake as natural beds in Chatham County, nearly all are below low-water mark, and there are no ledges now, nor have there been for years, to supply the spawn or the dropped-off oysters.

Ensign Drake indicated the location of a natural bed in the upper part of Tybee River, reaching from shore to shore, where it is 320 yards wide, and the nearest coon oysters are on a small bed at my landing, about 1½ miles below in Shads River. The only oysters in the main channel of Savannah River are about 80 acres of natural beds at its mouth, 900 yards from shore, and now being destroyed by the harbor improvements, with no coon oysters in the vicinity. The lowest density at the mouth at low water was 1·0090, and the mean of 29 observations at intervals of 4 hours was 1·0146, about the standard density.

That the set is not now more abundant on the old oysters and dead shells of the natural beds of Chatham County is attributable to the fact of their exhaustion and of their uncleanliness. The normal shape of these single oysters of all ages and sizes on the natural beds precludes the idea of coon origin. The river in South Carolina which best illustrates the effect of fresh water upon the life of the oyster and best proves the facts I have enumerated, is New River. It not only receives fresh water from the Savannah River through Walls Cut, but it drains Great Swamp and during every freshet the Savannah overflows into it through Great Swamp.

Mr. John D. Battle, in his survey of the coast waters of South Carolina, reports:

> The only raccoon oysters observed along the shores of New River are found between Ramshorn Creek and the mouth of the river, in narrow patches, about 10 feet wide, of dead shells and living oysters, the former largely in excess, due in a manner to overfishing in this limited area.

Had the survey extended higher up the river than Ramshorn they would have found some extensive, self-sustaining natural beds of single oysters in Tea Kettle Creek in a depth of 14 to 20 feet, about 4 miles above these ledges, and there are no coon oysters above Ramshorn. These beds supplied a part of the stock for the "Colossus Brand," put up last year by the Oemler Oyster Company, and a company located at Beaufort, S. C., had previously also used a steam dredge upon them extensively.

The Oemler Oyster Company planted 18,300 bushels of oysters in Wilmington River below Skidaway Island. Four months previously it had planted 38,496 bushels 2½ miles above this point in water of the same depth. Five miles still higher up, at Thunderbolt, is, according to Ensign Drake, the upper limit of ground fit for oyster-culture, on account of decreasing density, but here oysters, having grown naturally, are now successfully cultivated in a depth of 20 feet and over. The destruction of the oysters of the Oemler Oyster Company has increased with the increase of density over the grounds, notwithstanding the lowest were put down 4 months later.

In regard to the effect of floating and deposited silt, I will merely remark that it is greatest in the fresher waters. The water is purer near the sea, and, in consequence of the greater velocity of the current, the deposit is slighter. Exceptional cases of a set and of a bed below low water may and do occur near the sea in water generally of high density. Sometimes such a bed succumbs to adverse influences, after a few years' existence, to become rehabilitated under a phenomenal influx of fresh water.

The only case in Georgia of an oyster reef extending into the ocean occurs off the northeast point of Little St. Simon Island, where Ensign Drake found the density at low water to be 1·0067. At one-half flood tide it was 1·0124 at the surface, while at the bottom it was 1·0214. Three full-grown starfish were dredged up. One of them, placed in the surface water, died in twenty-four hours.

We know that attempts have been made to introduce the American oyster in France, and while it survives but will not spawn at Arcachon, in a density of 1·023, it perishes in the general density of the French coast of 1·026, the difference being only 0·003. Dr. Bashford Dean says:

> In the southern oyster the greater saltness of the water is at once apparent in the richness of many forms of food regarded as exclusivly marine, as *Triceratium farus* and several *Triceratia*, apparently undescribed, that I have seen in the Caribbean Sea. The lack of brackish-water diatoms affords a marked contrast to the Long Island forms.

It appears from the report of the North Carolina survey, by Lieut. Francis Winslow, that no oysters were found in the deep-water sections.

We know the density increases with the depth. Ensign Drake reported the surface density at the mouth of Wilmington River at 1·0271, which is in excess of the density fatal in France, and it was probably still greater at 20 to 35 feet deep, a little higher up the river, after the two seasons of excessive drought which had succeeded the planting and during which the river could have brought down only a small quantity of fresh water. Large lakes in Florida and Georgia had gone dry, as, for instance, Lake Newman, or Paine's Prairie, 68,000 acres; and Lake Miccosukee, 9,999 acres. I took out of the basin of the latter, about 3 acres in extent (at one spot 65 feet deep), with one seine, in four days, 123 barrels of terrapin, and 6 barrels with the first haul. All the trout had perished as soon as the water became stagnant. They had been so abundant that the dried carcasses still lined the shore. Buzzards had not been numerous enough to devour them, although I counted 91 on an area not more than an eighth of an acre. The shores of the lake had been pleasure-grounds for fishing parties from the neighboring counties of Georgia and Florida, and the lake had supplied the population with fresh fish; yet the neighboring farmers were congratulating themselves upon the destruction of the trout, because they had afforded a precarious support to and demoralized their labor. Whatever be the cause, the fact remains, that the deep waters of Georgia within or beyond the 1,000 feet limit must be excluded from ground heretofore held fit for oyster-culture, and it emphasizes the value of the last law, which slightly increased the actually valuable area subject to lease, especially in Chatham County. Without that accession Chatham County would have to rely, at no distant day, upon the cultivated crops from less than 100 acres to supply the population of Savannah (now over 50,000) and its entire oyster trade.

Ensign Drake estimated the entire area of the State fit for oyster-culture at 30,000 acres, of which 6,000 is outside and 24,000 inside the 1,000 feet limit, and of this latter the Oemler Oyster Company have demonstrated the unfitness of about 500 acres in Chatham County alone, and that of the entire 6,000 acres of the State in mid-stream.

When the oyster-canning companies went into operation they anticipated the temporary use only of the inferior coon oysters until they should be able to avail themselves of the product of their non-cultivated grounds, but the disastrous experience here and at Brunswick has shown that such companies can not become self-sustaining, because they now lack the territory on which to grow a better quality of stock than the native coon oysters. The best of these are not satisfactory and yield

As to the question of State boundaries, commissions were appointed by New York and Connecticut—that from Connecticut being led by Hon. Luzon B. Morris, the present governor of the State. The lines having been agreed upon by these State commissions, the agreement was ratified by the general assembly of each State, and afterwards by the Congress of the United States.

Many other questions arose in connection with this industry which required legislative action, and several questions of importance were settled in the Supreme Court.

Let us suppose that we have acquired a good title to a thousand acres of ground suitable for the cultivation of oysters and over which the water is not too salt or too fresh, too shallow or too deep. The first step is to buoy it out so that its boundaries may be distinctly marked, and that we may avoid planting the grounds of others. In the grant or designation its area and position is designated by distances from certain fixed points, such as light-houses, steeples, prominent rocks, etc. The buoys marking the limits of the ground are usually located in the first place by means of the sextant, angles for which have been previously taken from the map on which the grounds are marked. After the buoys have been once set by sextant, if carried away by storms or ice, they are usually replaced by cross ranges, using any prominent objects upon the shore or adjacent islands, such as steeples, prominent houses and rocks, light-houses and beacons. It is usual to take several different ranges, so that if the objects are destroyed in any of them, the others can be successfully used.

After the ground is buoyed we would place 30,000 bushels of adult oysters on it to furnish the eggs and milt to stock this thousand acres with oysters. A single female oyster produces several millions of eggs yearly, which, during the warmest weather, are expelled into the water, where they float hither and thither in the tides and currents. Doubtless but a small proportion are ever fertilized. Vast quantities fail to come in contact with the fertilizing element which also floats and swims in the water. Millions are devoured by animalculæ, and still more are destroyed by sudden falls of temperature in the surface of the water, caused by cold rains, at this critical period of the existence of the oyster.

The embryology of the oyster is an interesting study. In 1882, Lieut. Francis Winslow, U. S. N., well known for his able and exhaustive studies of the oyster under the direction of the U. S. Government, was with me for several weeks, during which time many millions of oysters per day were propagated under artificial conditions, and the impregnation, segmentation, and other interesting changes which they experience, were observed under the microscope. Many millions of oysters which had developed nearly to the stage of attaching, were deposited in Long Island Sound.

Sometimes infusoria would generate in the jars of water in which the oysters were kept, and would kill the oysters by millions.

The little oysters float about for several days, many of them on or near the surface of the water; after this roving existence, during which they are subject to many changes, the survivors reach what is called the "attaching stage," when they are ready to adhere to some hard, clean substance and commence a more settled existence.

The shells commence to form and the specific gravity of the shells assists in carrying them to the bottom. The greater proportion of the embryo oysters fall upon mud or fine sand and are destroyed. It is for this reason that we furnish hard, clean material to which they may attach themselves. After having planted our adult oysters to serve as parents for the new crop, our next step is to plant upon the same ground, in the month of July, from 10 to 20 times as many bushels of clean oyster shells or other hard, clean substance, such as broken stones, tiles, etc.

Upon this 1,000 acres we will suppose that we plant 500,000 bushels of shells, and by the end of July, in the climate of Connecticut, we begin to look with our magnifying glasses for the first appearance of the young oysters, which we shall hope have attached to the shells or other "cultch," which we have provided for them.

In some favorable years, the attachment or "set," as it is called, is very plenty, and most of the shells which are planted are well covered with the little oysters. In other years the "set" is very light, or an entire failure. Such was the case in 1889; due, as I believe, to the great amount of rain which fell in July, chilling the surface of the water suddenly and thus destroying the floating embryos.

In case the season is unfavorable and there is not an adequate quantity of the young set upon the shells, it will be necessary to replant the ground another year; but before doing so, it is desirable to catch up most of the shells previously planted and let them remain upon land for several months, for after they have been planted for a month or two, they have very little value for catching the "set," as they become coated with more or less sediment and vegetable growth, and are not available unless cleaned in some way.

After attaching, the oyster grows very rapidly and reaches in the fall about the size of a finger-nail, varying much, however, in the different localities and in different seasons.

When oysters are 1 or 2 years old, if there is an unusually large crop, it is necessary to catch a portion of them and transplant them to other grounds, so that they may have room to grow without crowding. If crowded they do not grow in good shape. Those experienced in the industry sometimes transplant large quantities of oysters from one kind of ground to another, for the purpose of improving their shape and making them fatter when marketed.

But the dangers to the life of the little oysters are by no means over when the attachment occurs, especially while they are still small. Vast quantities are destroyed by starfish, drills, storms, mud, sand worms, etc. The starfish has been the oyster's greatest enemy, but the drill is becoming even more destructive. The little starfish attach temporarily to the shells at about the same time that the young oysters do, and begin immediately to prey upon them. As they become older the starfish move in armies, as the grasshoppers and locusts do on land; an army of them will destroy thousands of bushels of oysters in a few days. I estimated the destruction of a crop of oysters planted by myself in 1882 at $90,000 in six months, while $9,000 were spent in the same period in catching the starfish which were doing the mischief.

For catching starfish, contrivances called "tangles" or "mops" are used, which consist of frames of iron attached to chains, which are dragged by the oyster steamers. To these frames of iron are attached about 20 small ropes, to which large bunches of coarse cotton-thread waste are fastened. As these "mops" are drawn over the beds, the starfish become entangled in the meshes of the cotton thread, and after a few minutes dragging are pulled to the surface by steam power; one drift of a few minutes sometimes catching as many as 1,200 or 1,500 starfish on a single "mop."

The common sand worm, *Sabellaria vulgaris*, is occasionally found in sufficient numbers to destroy a whole bed of young seed oysters. This is simply because in building their sand houses over the little oysters the oysters are smothered and poisoned by the sulphureted hydrogen thus generated.

The drill has been long found in our harbors and rivers, but for the last few years it has become much more plenty in the deep water of the Sound; they destroy vast quantities of oysters by boring a minute hole, about as large as a needle, in the upper valve of the oyster. The invention of some appliance for catching the drills is very desirable. I estimate the damage they cause at over $1,000,000 annually.

The periwinkle is another persistent enemy, but is more destructive to the older oysters, while the others mentioned work faster among the younger ones.

Occasionally vast quantities of oysters are destroyed by storms; this is caused by the agitation of the water when the wind is in such a direction and of such velocity as to cause a heavy sea. During the past August the damage by a heavy gale to the oyster industry has been estimated by some authorities at $3,000,000. At that time the wind reached a velocity of 53 miles an hour, and undoubtedly a large amount of damage was occasioned, but in my opinion the above estimate of loss was much too high.

For catching oysters from the farms steamers are now mostly employed. Previous to the deep-water cultivation oysters had been gathered by hand power, with rakes, tongs, and dredges.

In 1878, when I commenced to use the first oyster steamer owned in New Haven, it was said that steam could not be used to advantage in this industry, and its expense would consume more than the profits of the business.

There are now 68 steamers employed, one of which can take up 2,000 bushels of oysters in a day (more than 50 men can catch), in twice or three times the depth of water.

Oyster and fish culture have added much to the food supply of the world. We who grow oysters hope that you who multiply the fish will recognize us as in a common cause. We who devote our efforts to devising new methods of providing food can not have the honor to benefit mankind in the same way as those who minister to their religious, governmental, and educational needs, but so long as famine and want occur, if we help to prevent the suffering of our fellow creatures, we may hope in some humble degree to be classed, like "Abou ben Adhem," with "those who love their fellow men."

31.—BREEDING NATURAL FOOD ARTIFICIALLY FOR YOUNG FISH ARTIFICIALLY HATCHED.

BY A. NELSON CHENEY,

Editor of Shooting and Fishing.

It is an old maxim that nature's methods are the best methods; also that one can not improve upon nature. This may be true in a degree, but artificial fish-propagation, as practiced by modern scientific fish-culturists, refutes these statements in part and proves the fallibility of nature at least in one contest when opposed to the skill and fertile resources of man. When it was demonstrated that nearly 100 per cent of the eggs of fishes of the salmon family could be successfully hatched by artificial means, and that only 2 per cent of salmon eggs deposited in a natural manner were impregnated,* it was an achievement so great, so gratifying, and so productive of good to all the world that, figuratively speaking, the disciples of artificial fish-culture rested from their labors to view the result and listen to the plaudits of the world. This was but natural, fitting, and proper, for it was a grand victory; but when the victors were crowned some were crowned with laurel and some with poppy, from the soporific effects of which they have not yet recovered.

With the hatching of 90 per cent of salmon and trout eggs there was a return to natural conditions, and the helpless fry were taken from the hatching-troughs and planted in wild waters to take their chances where their enemies swarmed to prey upon them in their helpless state. Admittedly this was a great stride in solving the problem of restocking our exhausted waters, but there were men who were not satisfied with this result and were keen enough to see that other steps were required to make fish-propagation by artificial means a complete success. Something like six years ago the chairman of this Congress said to me:

> We are now seriously contemplating the establishment of a station for the special purpose of holding salmon and trout in ponds and feeding them until they are of such size as to be safe from capture by the small predaceous fish which swarm in some waters. I shall read a paper before the Biological Society at its next meeting, pointing out the reasons for our failure heretofore in successfully stocking waters with the fry of our salmonidæ. Failure in such work, barring a few exceptional cases, has been the rule, and will be confessed by those who are honest enough to confess their failures and wise enough to learn from them.

It requires courage of a superior order to admit of failure in any undertaking, particularly in a matter of this kind, that is a failure only in degree. In planting fish fry there have been so many successes that it made it more difficult to convince the satisfied fish-culturist that the system was wrong and a failure, in that it did not accomplish what might be accomplished by rearing the fry to a year or more of age before they were turned into wild waters. The U. S. Fish Commission was the first in this country to recognize the fact that the system of planting helpless fish fry was wrong, and quite naturally was the first to set on foot experiments to discover the remedy.

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*This is not guesswork, but the results of the actual count of the eggs in a salmon river in Canada, the details of which I gave in Forest and Stream, February 18, 1892.

Under date of December 4, 1889, Mr. Charles G. Atkins, superintendent of the salmon-hatching stations of the U. S. Fish Commission in Maine, reported to the Commissioner the details of his method of rearing the larvæ of certain flies as food for young salmonidæ, at the Craig Brook station of the U. S. Fish Commission. This report has not been printed in any of the Fish Commission publications, but an abstract from it was printed in Shooting and Fishing, December 26, 1889. I believe that Mr. Atkins is the only fish-culturist in the United States who has cultivated the larvæ of insects on a large scale for the purpose of feeding young fish. In England, Mr. Thomas Andrews, of Guildford, a noted pisciculturist, has cultivated insects and crustacea in breeding boxes and in ponds, as food for trout fry, and I quote from a letter he wrote me last year:

> My experience has taught me that one yearling fish is worth a hundred or a thousand fry for stocking purposes. * * * I get fewer fish perhaps (by feeding natural food), but I get monsters of 6, 7, 8, and 9 inches in a year, and my yearlings fetch three times the price of some other pisciculturists.

The system of Messrs. Lugrin and du Roveray, in France, of self-reproducing food for young fish, has been practiced in Gremaz since 1884, and is too well known to need more than passing mention, as it is not unlike the method pursued by Andrews, and it has been adopted by Muntadas in Spain, and is printed in detail in the Bulletin of the U. S. Fish Commission for 1887, and is copied into the proceedings of the American Fisheries Society for 1892. I do not pretend to mention all of the fish-culturists at home or abroad who practice this rearing of natural food for young fish, and what I have said has been said briefly, only that I might introduce a new experimenter in this particular field.

Early in the current year I wrote an article for the distinguished German fish-culturist, Max von dem Borne, upon the "results of artificial fish-culture in the United States," and this being translated and printed in an Austrian newspaper, was read by Carl Edler von Scheidlin, an Austrian engineer, who wrote me a letter, from which I make this extract:

> The first and most important question to be solved in the artificial culture of all fish is as to the proper food for them with reference to their kind, stage of growth, and the purpose they are to serve. This question, so long unsolved by all nations, I, by following further on in the line of the Frenchman, Lugrin, have solved, and have tested the solution as good, cheap, and practically feasible.

Mr. Von Scheidlin proposed to make over to me for use in the United States his method of rearing natural fish food, which is called "The Scheidlin-Rakus method of fish breeding and feeding," and I entered into correspondence with him to this end. I have already received several long papers on the subject, but the correspondence has not reached that stage where it would be proper to enter into the details of the system, but when all the papers promised are received I shall turn them over to the U. S. Fish Commission, and if they prove to be what I now believe they will, the system of Mr. Von Scheidlin will probably be made known by the Commission. In the meantime, I quote from the letters already received:

> The entire question of the food of fish rests upon two important points: (1) Upon the recognition of the fact that their food consists of insects, infusoria, crustacea, worms, amphibia, and fish, in their various stages of transformation; and (2) upon the observation of the fact in nature that the females of insects, amphibia and fish deposit their spawn only in those places in which are found suitable conditions for the future survival of the young; and if the pisciculturist produces these conditions according to the needs of the animals, he can induce them to deposit their brood in definite places, and can produce the food for the fish wherever he likes, and in greater quantities than are produced in the waters by natural processes. Fish food should be living and consist of bits or pieces as large as the mouth-opening of the fish to be fed.
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> The principle of rational feeding according to Justus von Liebig, Boussingault, and Gronven, is briefly this: The chemical composition of the food should conform to the chemical composition of the body of the animal to be fed—that is to say, in the case of fishes, being cold-blooded animals, they must receive food that in turn consists of cold-blooded animals—a principle that runs through all nature. For example, you can raise maggots easier, quicker, and in greater quantities upon the flesh of amphibia and fish, than upon that of mammals. * * * One kilogram of food composed of insects, amphibia, or fish, is equal in quantity to 16 to 18 kilograms of the flesh of mammals.
>
> By means of natural food the fish fry grow seven times faster than by the food of mammal flesh. * * * Since May of last year [the letter is dated in August, 1893] I have been feeding carp fry with artificially-reared natural food, and the fish which when put into the pond were 1½ centimeters long (10,000 of them to 114 acres of water surface) are to-day 16 to 18 centimeters long. Those that were 18 decigrams in weight are now 3½ kilograms, and those that were 5 decigrams are now 1 to 1½ kilograms. * * * Of all these natural foodstuffs, 2½ to 3 kilograms produce the same increase in the fish fed as 14 to 20 kilograms of the flesh of mammals, and it is produced three-fourths cheaper with the natural food. * * * Two years ago I produced within 100 days by means of natural food, from carp fry 1½ centimeters long, carp of 1½ kilograms in weight.

At the risk of repeating a portion of the substance of what has already been quoted from these papers, I will give one more extract:

> Not till now do I see from your letters that you lay the greatest stress upon the culture of young fish up to the first or second year; and that is the correct idea and the one I hold to myself. The food of the brood after the loss of the umbilical sac must be *living*, not finely-chopped mammal flesh, because while the fish upon the latter diet may become large they will not become strong. If you can not give them living food give them, at any rate, finely-chopped fiberless amphibia or fish flesh, as this is 50 per cent better than mammal flesh, while living food, on the other hand, is 1,000 per cent better.
>
> The production of living food for brood and young fish is the easiest and cheapest, and this food can be fed until the fish have grown to 15, 20, or 30 decigrams, when they must have more substantial food, such as earth worms, beetles, larvæ, maggots. * * This year I introduced my method of young fish feeding in two trout-breeding establishments, as a test, in order by the result to make a reputation for my method. Both establishments were in the habit of feeding horseflesh. The one fed 50,000 the other 80,000 fish-fry, so that in two years they were fish of 1 to 2 kilograms. By my method both establishments used only one-seventh of the food formerly used, and the cost of food per kilogram was reduced more than one-seventh. One increased its plant to 120,000, the other to 200,000.

One of the "foodstuffs" reared by Mr. Von Scheidlin is the larvæ of flies, and it is interesting to note that his method is very like that practiced by Mr. Atkins already referred to. Mr. Von Scheidlin tells me that as the result of 30 years' experience and experiments in fish-culture he is fixed in his belief that to obtain the best results young fish must be fed until they are at least 1 year of age before they are turned out to seek their own living, and certainly 30 years' experience should count for something.

32.—WHAT WE KNOW OF THE LOBSTER.*

BY FRED MATHER,
Superintendent of New York State Hatchery at Cold Spring Harbor.

Within the past five years we have learned much of the life-history of the common American lobster that is new, the most important item being a discovery of its spawning habits, which will simplify our attempts to hatch this valuable crustacean on a large scale. We knew that the female lobster carried a mass of eggs under her abdomen or "tail," as it is improperly called, and that they hatched there, or that we could hatch them under proper conditions of temperature and density of water, and there our knowledge of lobster propagation ended. There are many other things about the life of the lobster that are not popularly known, and without going into a technical description of its anatomy, we may find much to interest us in its habits, development, mode of reproduction, and other incidents, from its emergence from the egg to its capture for market, where we will leave it to the mercies of the *chef* and the lesser deities who preside over our kitchens.

To begin at the beginning is difficult. It recalls the old problem, "Which was first, the egg or the hen?" But in order to break into the life circle we will begin with a small lobster of a few months old, say in September. The temperature is lowering and no more growth is to be made until next year; therefore a gradual movement toward deeper water is begun in order to be beyond reach of the rapidly cooling waters near shore and to get below the influence of frosts, as the tortoises, frogs, and some of our land mammals do. At this time our young lobster will measure from one to two inches, exclusive of the claws, according to the circumstances of food and the date of hatching, the latter being entirely a question of temperature. Living at a depth where there is sufficient warmth to sustain life, but not enough to rouse much of an appetite, our young lobster lives through the winter without making any growth, and in the spring crawls up, as the waters warm, into the shallows and begins to feed on such animal forms, alive or dead, as may come within its reach.

Incased in a hard, unyielding shell which does not grow, it may be compared to a knight in armor, who would be obliged to get a new suit if he should outgrow the old one; therefore, after accumulating a store of material for growth, the shell either splits up the back of the carapace or the latter separates from the first ring or segment of the abdomen and the hinder portion of the animal is withdrawn, and then, with great labor, the forward parts follow and the lobster lies soft and helpless, a toothsome morsel for any predatory fish that may chance along; but instinct teaches the lobster that down among the crevices of the rocks is a sanctuary, and there it remains for several days until the skin hardens into a new shell and it can again fear-

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* Printed in the Scientific American Supplement, February 10, 1894.

lessly face its enemies in search of food. It has been my fortune to witness this operation several times while connected with the New York Aquarium, Thirty-fifth street and Broadway, in 1876-78, and twice since in lobster cars in Vineyard Sound, and it is wonderful what a great increase in size takes place at once after the animal leaves its shell. Another wonder is how the great claws are drawn through the very small joints, one or two of which split lengthwise while others seem to soften and expand enough to permit the passage of the claws. When we realize that the lining of the stomach is attached to and cast with the old shell, it will be seen that the change of armor is a complicated and difficult process, not unattended with danger. The new shell is often to be seen under the old one, and then the lobster is in the same condition as the "shedder" crab, so eagerly bought by salt-water anglers for bait, the body being somewhat shrunken from the shell. After casting the shell, the lobster resembles the "soft" crab, which is so esteemed by the epicure that they are sold at many times the price of the "hard" crab. These names apply to the common edible or "blue crab," of the Atlantic coast, at different periods of growth.

There is a singular prejudice among lobstermen against eating a soft lobster, which does not extend to epicures. I have eaten of them when soft, and I think them excellent; surely the animal is fat and in prime condition or it would not shed preparatory to taking on greater size. Just how long it may take for the new shell to harden may depend on temperature or other conditions. One in the New York Aquarium, in summer, became quite hard in about twenty hours, and took food the third day after shedding. There seems to be a provision of nature that the female shall not cast her shell until the eggs are hatched, otherwise they would be lost, as they are greedily devoured by eels and other fish. The law of Massachusetts forbids "berried" lobsters to be sent to market. The honest lobsterman, therefore, puts such a lobster in a car which has holes large enough to admit eels, and in twenty-four hours she can be sent to market in compliance with the law, for she will have no eggs left.

I have purposely skipped from the little lobster that we left foraging on his first spring campaign to the habits of the adult, which are the same, because we know nothing of the rate of growth beyond the first season. We know that lobsters shed their shells at irregular times during most of the year, more frequently in the warmer portions, and that this only occurs because the creature is growing and its armor is not large enough. Just how old a marketable lobster of 2 to 10 pounds may be, no man knows, and such knowledge could only be obtained by rearing them in confinement, and then it might not be conclusive under different circumstances of food and temperature, and the casting of the shell forbids marking individuals.

The female spawns but once in two years. Notes made on the eggs of lobsters in the New York Aquarium show that they hatched before July, or when the water reached a temperature of *about* 60° F. In 1891 I began the hatching of lobsters for the New York State Fishery Commission, of which I am one of the superintendents, and found that eggs taken from lobsters from the middle to the last of July did not hatch that year. Then it seemed as if the lobster might be a biennial spawner, but I did not dare to say so. A report of my observations sent to Prof. Samuel Garman, of the Museum of Comparative Zoology, Cambridge, Mass., brought a letter dated August 30, 1892, complimenting my studies on the life-history of the lobster and inclosing a report to the Massachusetts Fish Commission, dated December 17, 1891, in which he shows that his investigations proved that the lobster spawned but once in two years. Therefore, I have solid backing in making the statement that heads this paragraph.

Since this I have taken, for the New York Fishery Commission, a large number of lobster eggs and have turned out this year from Cold Spring Harbor, Long Island, 177,000 young lobsters into the waters of Long Island Sound. These were from eggs which otherwise would have been sent to market with the parent and have been boiled and thrown away with the shells, and were therefore just so many saved from destruction and given a chance to struggle for life. There is no law in the State of New York relating to "berried" lobsters, and from what is said above of the Massachusetts law, it does not seem that one would be advisable, unless so framed that the lobsterman should take the eggs from the lobster and either keep them in a place where they would hatch or, better yet, save them for an agent of the fishery commission, who could collect them at intervals and would reward the lobsterman sufficiently to make him interested to turn in as many good eggs as possible.

The eggs, which, as before said, are carried on the appendages under the abdomen, number 15 to the linear inch, and measure 6,090 to the fluid ounce, are attached not only to the swimmerets, but also to each other by threads, and are aërated by an almost constant motion of the appendages, and in confinement many eggs are loosened and fall off, perhaps from the habit that the parent has of poking among them with her legs. In the spider crab this poking is not only frequent, but the eggs are eaten by the parent, at least when in confinement, but I have never seen a lobster eat its eggs. It has been said that lobsters spawn at all times of the year. This is not so, for the reason that they are not as active in winter and do not feed as much as in summer, and also because the young do not hatch until the water reaches a temperature of about 60° F., which in Long Island Sound might occur after the latter part of May, and in that region the hatching season is over by the middle of July, and as the mother has been feeding while carrying her eggs, she can then shed her shell and begin to develop the so-called "coral" that epicures prize, which will form the eggs to be laid the second year. The fact that female lobsters bearing eggs outside while others have the coral inside are taken in winter supports the theory of biennial spawning. August 16, 1893, I took a lobster from a car which the owner told me had spawned two days before. The microscope could detect nothing in the eggs, because the yolk filled them entirely. Four days later the yolk had shrunken and the "mulberry" stage could be seen in the clear space, and by the 25th the eye was visible. The eggs are dark when first laid, and grow lighter in color as they develop. From this until October no change was seen. The water growing cooler, the mother did not take as much food as before, but seemed as pugnacious as ever, showing fight to anyone who approached the glass. At present she is living in a tank about 12 by 18 inches and may live all winter. She had been plugged in the claws to prevent danger in handling, but I removed the plugs, and she can now use her claws as well as ever.

When our little lobster comes from the egg an inexperienced eye might easily suppose it to be a young shrimp or any other crustacean, for, unlike its fresh-water prototype, the crawfish, which at hatching resembles its parent in everything but size, the young lobster is an embryo or larval state, as much so as an embryo trout, which has no resemblance to its parent. It molts perhaps 4 to 6 times during the first ten days of its life, and makes, according to Prof. S. I. Smith, of Yale, three changes of form in this time before getting the large claws and assuming the shape of its parents. They swim throughout all these changes and perhaps long after, which makes it certain that a plant of young made at a particular spot may be repeated many times without danger of overstocking that locality, for as they swim away the tides and currents scatter them, and when the time comes to settle down to steady habits they are wide apart. Still, as the plantings made by me for the New York Fishery Commission were all made at Cold Spring Harbor, on the south shore of Long Island Sound, some 15 miles west of the middle of that body of water, the varying tides would not take the little swimmers outside its limits, because the returning tide would bring them back again. Therefore there is no doubt about the value of saving the lobster eggs and planting them in the sound. Some New York lobsters may cross the sound and be taken in Connecticut traps, just as New York salmon and shad are taken by New Jersey fishermen, but that is not a thing to be considered seriously.

A very natural question for a reader to ask at this point is: "Why don't you retain the youthful lobster until it ceases to swim and settles down to crawling, and thereby stock a certain district in which your State, that pays for the work, is interested?" To this I should reply that in theory that would be the proper and most correct thing to do, but in practice we find that there is a factor that will not be left out of our calculations, and this factor is cannibalism.

There is, at present writing, no food for a larval lobster known to me that is as acceptable as another larval lobster that has just molted. I have tried to bribe them by hanging flesh of eel, clam, beef, lobster (adult), blue crab, and fiddler crab, but without avail; their love for their fellows which prompted them to take their brethren in out of the wet, lest they might be devoured by small fishes, baffled my efforts, and there was no resource but to plant the fry as soon as hatched. If each youngster could be placed in a tank or even a small compartment by itself, no doubt it would accept any, or all, of the foods named, but at present we are not prepared to feed a million or more individual lobsters in separate stalls for months before turning them out to shift for themselves. They cannot be reclaimed from cannibalism by any known means. They are fighters by nature, and when a lobsterman has a lot of adults in a floating car and a storm comes up each lobster blames his neighbor for any collision that may ensue and they engage in a general fight, which is not only disastrous to themselves but to the lobsterman, for lobsters are not marketable in fragments.

The size of marketable lobsters has been on the decrease for the past fifty years. Half a century ago my father never brought home a lobster for family use under six pounds, and it was often twice that weight. One under six pounds was not thought worth picking the meat out of, for the labor is the same, no matter what the size; but to-day a 2-pound lobster is considered of good size, although an occasional "deep sea" lobster of 20 pounds, or more, is seen on the stands. These usually have large barnacles, oysters or other animals of good size attached to their shells, showing that they have not molted in some years, and their claws are always bruised and blunted as additional evidence that their armor has not been recently renewed. The taste for "chicken" lobster has done much in recent years to kill off the young and to prevent their attaining a larger size, but the canneries are credited with taking in all that may be rejected by law. The State of New York had a law that no lobsters measuring less than 10½ inches, exclusive of claws, should be sold. This excellent law was, I believe, obtained by Mr. Eugene G. Blackford when he was president of the New York Fishery Commission, but was repealed.

That lobsters of 20 pounds weight have been taken within a few years I know, for I have seen them weighed; but the monsters of twice that weight that we read of are not well authenticated, and the story of the judge who, after the manner of

Solomon, decided a bet on the weight of these crustaceans against the man who brought sworn testimony of old fishermen, who remembered lobsters of 40 pounds, by saying "affidavits are not lobsters," has passed into history. A century hence, my statement of having seen a 20-pound lobster may be received in the same way, and some judge, yet unborn, may paraphrase the above decision, and solemnly declare that "statements are not lobsters."

A curious thing about a lobster is the difference in its claws. One is thick and blunt and the other is long and slender. One seems to be for crushing hard objects and its mate seems formed to hold them. This is the case with every individual, but there are right-handed and left-handed lobsters. Some years ago Mrs. Mather painted lobsters surrounded by celery, oil, vinegar, and all the necessaries for a mayonaise, but one of the lobsters had the big claw on its left. When allowed to see it, I remarked that there was either a mistake or her specimen was abnormal. She insisted that the original must have been so, and on my next visit to Fulton Market, where over 100 lobsters were handled for my edification, I found that a lobster might be either right or left handed without violating any rule, and then made my apologies to the artist.

The color of lobsters sometimes varies from the ordinary olive-green, with reddish tints on the claws, to red all over, and a mottled coat is quite often seen. Red ones are quite rare, and the few of this color I have seen have been lighter than the boiled lobster, sometimes with a yellowish cast. The cause of the variations is not known.

The lobster feeds upon animal food exclusively, for its digestive system could not assimilate vegetation. Its stomach is a sac, just behind the mouth, and has no other opening, save the small pores through which the digested portion of chyme or chyle is filtered into the thorax, there being a space of some inches between the stomach and the only intestine, or drain tube, which begins at the first segment of the abdomen and runs without convolution to the cloaca. The stomach is fitted with rough, bony plates to masticate the food, and when opened shows a fanciful figure called "the lady in the chair." All bones and undigested portions are ejected through the mouth. In dressing a lobster for the table, the so-called "poisonous parts" are rejected. They are the stomach, which could not be eaten, and the vein-like intestine spoken of. To remove the latter it is only necessary to split the abdomen, or so-called tail, lengthwise, when it will be seen as a greenish thread. All other parts are eatable, and the tender green "fat" in the thorax, and the delicate, white "fat" lining its shell, should never be lost, as they contribute both flavor and digestibility to the harder portions.

The lobster does not range far south on our Atlantic coast, because it is sandy south of New Jersey, and does not afford protection for them when in the soft state, even if other conditions were favorable. Large individuals are sometimes taken on the coasts of Delaware and Maryland, and they range as far north as Labrador, the best lobster grounds of the Atlantic being Nova Scotia and Maine. They were formerly abundant in Long Island Sound and about New York harbor, but the pollution of the waters, especially with "sludgeacid" from the petroleum works, has driven them away. This abominable stuff does not drift far, but settles on the bottom, and, while it may not disturb the shad and salmon, which are migratory, it kills out the oysters, clams, mussels, snails, and all those forms that live on the bottom, including the lobster, and compels the fishes which seek food in those waters to go elsewhere. The canning of small lobsters in Maine may affect the product there, but the worst of all enemies is man. Of all the destructive agents to animal life of most kinds, man stands at the head, at once the wisest and most ignorant of all animals. His ignorance is especially in contrast with his intelligence, when he deals with other creatures. And the lobsterman is an instance; he wants to see lobsters plenty, because he finds a ready market for all he can get; but, when he raises a lobster pot and finds that two or three small lobsters of 4 or 5 inches in length have ventured to eat the whole or part of his bait, he is angry, and, instead of returning them to the water to grow, he mashes them on the bottom of his boat. As well might the farmer shoot his young fowls for eating his grain! The lobster will eat fish, clams, mussels, and other animal food, fresh or stale, but in the pots a fresh bait is more attractive, and the lobstermen use almost all kinds named for bait, and could, with small expense, so make their traps that, when a lobster entered the pot, it could not devour the bait, and so afford to let the young go free if the larger ones did not devour them in the pots.

The power of the lobster to reproduce a leg or claw is well known. It is not done until the next molt, when the new limb appears as a very small model of the original, but after a few changes of shell the claw is restored to its normal size and usefulness. The animal can and does cast a claw when frightened, especially in cold weather, probably to satisfy its captor with a portion instead of the whole—a tub to the whale, as it were. The claw is snapped off with a jerk, as if to say, "Take this and let me go." The lobsterman never lifts the animal by its claws for this reason, but grasps it by the thorax, leaving the large claws to hang down or turn up in a vain attempt to pinch his hand.

Our friend has two means of locomotion. When in danger it can go backward rapidly by means of a few vigorous flaps of its tail, but ordinarily it crawls forward on the bottom, holding its large claws well up. If left in a pool by the receding tide, it would stay there and perish before trying to go overland to the sea, even if not 10 feet away.[*] When taken from the water the lobster is very helpless. Its specific gravity is great; its enormous claws can not be lifted in air, and when laid on the market slabs it remains where it is placed from sheer inability to move.

Just how the eggs are impregnated is not known. It is said that the milt is placed near the oviduct some time before the extrusion of the eggs, and that they are fertilized by passing over it. Of this I know nothing, and merely insert this paragraph to show that this question was not overlooked. The sexes of lobsters can easily be distinguished without the presence of eggs, but it is no part of my purpose to enter into the realm of anatomy or theory, as the title of this paper is "What We Know," etc.[†] When the pairing takes place and how it is performed no man knows. A study of the reproductive organs has developed a theory, and there we stop.

The increase of population has naturally increased the consumption of lobsters, and the great decrease in the size of this crustacean, referred to above, is an evidence that they are slow of growth, and the marketable lobster of to-day, weighing from one to two pounds, may be from four to six years old, possibly more. In all these estimates of weights a fairly plump, well-fed lobster is meant, and not one that would be rejected by the housewife as not worth picking the meat from, for she has learned to weigh them in her hand, and of several of the same size, to choose the heaviest.

We hope to increase the supply of lobsters by saving the eggs from destruction, but the ever increasing demand for them will prevent their becoming cheaper.

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[*] See Eighth Report New York Fish Commission, 1875, p. 23, tenth to eighth lines from bottom.
See "Fisheries Industries," section 1, pp. 795–809.

33.—REMARKS ON THE MAINTENANCE AND IMPROVEMENT OF THE AMERICAN FISHERIES.

BY HUGH M. SMITH, M. D.,

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Address as Chairman of the Fisheries Section of the World's Fisheries Congress, Columbian Exposition, Chicago, October 18, 1893.

In opening this session of the Fishery Congress devoted to the commercial fisheries, the apparatus and methods of fishing, and the utilization and handling of fishery products, I desire, in the short time I shall occupy before proceeding to the business of the meeting, to invite your attention to a few thoughts regarding the general field which lies open for our consideration, and to point out some of the important questions with which those interested in the prosecution, maintenance, and regulation of the economic fisheries have to deal. I shall speak chiefly with reference to the preservation of our fisheries and to certain benefits which may be expected from changes of methods and means of capture and utilization.

Conspicuous instances now exist of the general or local decline, failure, or threatened exhaustion of some of our important river, lake, shore, and ocean fisheries. Among the river fishes whose present extent is markedly less than at an earlier period are the sturgeon and the Chinook salmon; of the lake fishes which are notably scarcer than formerly are the whitefish and sturgeon; lobsters and terrapins, among the shore fishery objects, have undergone a serious diminution in abundance; and the ocean fisheries for whale and mackerel are, as is well known, much less valuable than they were a few years ago. In nearly all these cases the decrease is undoubtedly due to unwise and wasteful methods, and it is an open question whether the decline in many of our sea fisheries may not be at least partly attributable to the same cause.

In view of the increasing importance of our fisheries as a source of national wealth and food supply, it is not especially remarkable that the present period should be characterized by a deeper appreciation of the necessity for preserving our natural fishery resources, a more determined effort to ascertain the conditions prevailing and the influences operating, and a fuller realization of the urgent need of more definite knowledge regarding many of the phases of the fisheries than have existed at any previous time in the history of this industry.

The present time is also marked by a wonderful spirit of progress in fishery methods and an assiduous search for improved appliances. Forms of apparatus, types of vessels, methods of capture and utilization, which a very few years ago were employed are giving place to improvements directed to an increase of the catch, a reduction of the labor, and a mitigation of the hardship and danger of fishing.

The entire aspect of our fishing industry to-day, in its protean manifestations and multitudinous relations, warrants the earnest consideration of all those engaged in its prosecution, intrusted with its regulation, or concerned in its welfare, in order that such action may be taken as will preserve this great source of wealth for the present generation and transmit it unimpaired to posterity. This idea has been well brought out in the interesting paper presented by Dr. MacCallum at the opening of this congress.

As to the ultimate success of the measures for the restoration and preservation of our lake, river, and shore fisheries, I entertain no doubt. The history of our black bass, shad, and oyster fisheries, for example, shows the possible influence that man may exert on the abundance of our economic water animals by adopting positive or direct methods for the increase of the supply, rather than by placing sole reliance on legal restraints on the capture of the products.

As an offset to the degeneration of some of our prominent fisheries through the influence of man, stands the unquestioned improvement that has been effected in other fisheries through the same instrumentality. I think the facts bear out the assertion that the decrease in the value of those fisheries which to-day present a decline as compared with the most prosperous period of their existence is less than the increased production of other fisheries as the direct result of artificial methods employed for their maintenance or improvement. The oyster alone, owing to the adoption of plans for its active cultivation and preservation in nearly every oyster-producing State, in contradistinction with the do-nothing policy that formerly and so long prevailed, has increased in value as an economic commodity to an extent that almost overbalances the combined decrease of all other fishery products.

There is reason for great satisfaction with the results achieved in behalf of the commercial fisheries by artificial propagation. There seems little doubt that the most important river fishery of the Atlantic coast, that for shad, is almost wholly dependent for its present existence and future prosperity on the means taken by fish-culturists to aid nature in securing the fertilization and hatching of the largest possible percentage of ova. The noteworthy results accomplished on the Pacific coast by the experimental introduction of relatively small numbers of shad fry into a few of the rivers afford an invaluable basis for determining the influence on the abundance of shad in native waters of enormous annual plants of fry and yearlings. The recent inauguration of a shore cod fishery on parts of the New England coast where cod were previously scarce or almost unknown is unquestionably attributable to the hatching operations of the U. S. Commission of Fish and Fisheries, and has proved conclusively that, even in the case of such an eminently pelagic species as the cod, man may be potent in influencing its abundance.

Few subjects connected with the commercial fisheries are more important than the relations which exist between the kind and quantity of apparatus used in a given region, on the one hand, and the supply of fish, on the other. Unquestionably, certain modes of fishing are more destructive than other modes, and some forms of apparatus are more harmful than other forms, independently of the quantities of fish that may be taken. Paradoxical as it may seem, it is nevertheless true that two different kinds of apparatus, taking exactly the same quantities of fish at the same time, may be very different in their effects on the maintenance of the supply; and, again, two similar devices operated under the same conditions and taking the same quantities of fish, but at different seasons, may also have widely different influences on the ultimate abundance of the species captured. In other words, the character of the apparatus does not necessarily afford a basis for determining its effects. A number of modifying causes and circumstances are to be taken into consideration in determining the actual and relative effects of apparatus, among which are: (1) the season when the fish are caught; (2) their condition with relation to the spawning process; (3) the fishing-ground, especially with reference to the shore or the spawning beds; (4) whether the fish are taken in schools, singly, or in straggling bodies.

One of the most vital questions now before the fishery interests of the Atlantic coast is the effect of the purse seine on the abundance of mackerel and menhaden, The failure, year after year, of the mackerel fishery has, to many persons, seemed a positive demonstration of the injurious influence of the purse seine. Granting the present relative scarcity of mackerel on our coast to be due to the effects of unrestrained fishing, the fact should not be lost sight of that many more fish were taken in the old days of hook-and-line fishing than have been caught with the purse seine; and even conceding that the purse seine is responsible for the conditions now prevailing, care must be exercised in ascribing to that apparatus its particular influence in reducing the supply of mackerel, especially in view of the easily verified statement that less fish have thus been directly sacrificed than by the methods pursued prior to the introduction of the seine. The question does not seem to be, Has the purse seine caught too many mackerel? but, Has it taken them under conditions that were unfavorable for the continuance of supply? The apparent maintenance of the supply of menhaden on our coast, in the face of an exceedingly large annual catch, even in a circumscribed area like the Chesapeake Bay, is an argument on the opposite side of the question. Similar references might be made in the case of certain other fishes obtained with pound nets, trap nets, and other forms of apparatus which take large quantities of fish and are, in the opinion of some, responsible for the decreases that have occurred, while other fishes captured under the same conditions and in as large, or even larger, numbers, are apparently holding their own.

While no one attempts to deny that by the reckless use of fishing apparatus in many of our rivers, lakes, and shore waters certain fishes have decreased very noticeably in abundance; and while it is entirely possible, by the abuse of appliances, to effect almost irreparable injury on the fish supply of more or less circumscribed bodies of water which years of rigid protection and extensive artificial means may not be able to overcome, still it is far from being an easy question to determine to what extent the capture of free-swimming fish in the open waters of the ocean may go without producing a perceptible diminution in the supply or vitiating the natural fecundity of the species.

I think we have reason to expect that the studies of the life-histories of our economic marine and fresh-water fishes now going on, when taken in connection with investigations of the fisheries for these species, will do much to solve many of the problems and explain many apparently contradictory phenomena now presenting themselves in connection with our economic fisheries.

The necessity for restriction in certain lines having been determined by competent authority and proper means, the reform should be promptly and efficiently carried out; and I believe that no one will be more ready to accede to rational measures for the preservation of a fishery or the perpetuation of a species than the commercial fisherman. But sentiment and prejudice, unsupported by facts, should not be allowed to abridge or destroy a long-established industry.

In an able paper, which every one interested in the fisheries, from whatever standpoint, should read, presented to the International Fisheries Exposition in London in 1883 by Prof. E. Ray Lankester, the author laid stress on the importance of scientific study and knowledge as a basis for legislative restrictions; his remarks are so timely that they may well be quoted in part:

> Legislation is continually demanded, and has been from time to time carried out, in reference to such matters as modes and seasons of fishing and pollution of waters. But it is undeniably true that, in most cases, the accurate knowledge as to the life-history and circumstances of fishes is too small to justify legislative interference. No doubt zoologists have suggested some valuable restrictions which have been adopted by the legislature in regard to some fisheries, and it is to Linnæus, the great Swedish zoologist of the last century, that Sweden owes important fishery laws. But if we are to have effective legislation at the present day in regard to our sea fisheries, we must, before proceeding any further, have *more knowledge*. Those (and there are many) who earnestly desire additional restrictive fishery laws should do their utmost to enable zoologists to carry on researches which will provide that accurate knowledge of fishes and shellfish, their food, reproduction, and conditions of life—which must be obtained before legislation can reasonably be proposed. The only mode of deciding between the conflicting opinions which have so often been expressed during this congress, as to the necessity for this or that legislative enactment, is by bringing new knowledge to bear upon the questions at issue. That new knowledge is nothing more nor less than a part of zoological science, and can only be obtained through the exertions of those who are already acquainted with the actual condition of that science, and with its methods of minute and thorough investigation.—(The Scientific Results of the Exhibition)

Next to an abundant supply of fish, and of probably greater consequence from some points of view, is the importance of having the fish reach the consumer in the best possible state of preservation. Improvements in the construction of fishing vessels, the more general use of ice, and the more ample facilities for transportation which exist, have already done much to improve the quality of the fresh fish landed from the high seas and the Great Lakes, but the interests of the fishermen and of the public urgently demand further reforms in this direction. The very rapid deterioration of fish which ordinarily ensues upon their capture, owing to the large percentage of unstable albuminoids entering into their composition, requires more serious consideration on the part of fishermen and dealers than is usually bestowed.

Certain modes of capture are responsible for placing on the market an inferior article of food which, under other conditions, would be all that is desired. Fish that are caught by the gills and are left to die in the water by slow degrees undergo a rapid decomposition which quickly unfits them for consumption. The pernicious practice, especially prevalent in Lake Erie, of setting such long lines of gill nets that they can be lifted only at intervals of several days, results in the destruction of enormous quantities of whitefish which have to be thrown away and of very large numbers that are of poor or doubtful edible value. If there is one line of fishery legislation for the Great Lakes more demanded than another, it is the prohibition of the use of gill nets that are not drawn daily.

The generally observed custom of permitting fish that are landed alive to die slowly is also to be condemned on hygienic and economic as well as humane grounds. The longer the time occupied in dying, the softer and less wholesome the flesh becomes.

Fish that are killed immediately on being caught retain a firmness of body and bear shipment better than those which are permitted to die a lingering death, a fact which is well known.

While the extensive use of ice during the fishing operations and in the transportation of fish greatly reduces the impairment in quality, still the present generally pursued method of applying cold for the preservation of fishery products is far from being satisfactory. A person witnessing for the first time the unloading of a vessel engaged in the market fishery for cod and other ground fish, is bound to be forcibly impressed with the soft, slimy, and uninviting appearance which the catch presents when taken from the hold, notwithstanding the evisceration of the fish soon after being caught, and the use of large quantities of ice applied directly to them.

This is one of the lines along which improvements are to be suggested, in the interest of a better quality of fish, as well as for the pecuniary benefit of the fishermen. Vessels often arrive from distant fishing-grounds during the warm months with thousands of pounds of soft and stale fish in their holds, and with little or no ice. The moisture which the melted ice imparts to the fish favors the development of putrefactive bacteria and accelerates decay. The impairment of the quality of fish which ensues when insufficient means for their preservation are taken can never be dissipated by secondary attempts to stay the deterioration, and the most careful efforts to maintain the freshness of the fish should be made at the time they are caught and pending their arrival on shore, and not from one to ten days after being taken, as is now too often the case.

Among other things that seem to be demanded in the interests of fresher fish is the construction on fishing vessels of dry-air refrigerators. Much good will also accrue to the fisheries by the use of steam fishing vessels and steam carriers in the offshore market fisheries, not only by permitting the discharge of the catch in a better condition but also by enabling the fishermen to visit more distant grounds. The successful efforts of dealers to properly handle fish on shore, prior to and during shipment, by the adoption of modern refrigerator and rapid-transit facilities, fix on the fishermen the necessity for making further improvement in the quality of the fresh-fish supply.

Much, I believe, may be done indirectly for the protection and preservation of some of our fishes now decreasing in abundance by devoting attention to other fishes now rarely or imperfectly utilized, in order to keep up the supply of fish food. The history of the sturgeon, eel, and other species in the United States affords ground for the belief that many fishes now considered worthless may be brought into favor and thus reduce the destruction of other more valuable fish. Already the much despised skates are becoming a factor in the food supply of the Middle Atlantic region and are materially contributing to the income of the fishermen, as they have long done on the west coast; but there are numerous excellent fish in our waters, some of which exist in almost limitless numbers in certain places and at certain seasons, that are scarcely utilized. Among these, and deserving of special mention, are the sea-robins (*Prionotus*) and the whiting or silver hake (*Menticirrus*). Sea-robins, which are taken by thousands of tons on the southern New England and Middle Atlantic coasts and are almost invariably thrown away, are very similar morphologically and scarcely, if at all, inferior in food value to the highly esteemed gurnard of our English brethren. The whiting, one of the *Gadidæ*, in a perfectly fresh condition, is superior to the cod, and when pickled is a valuable article of food; yet only a few thousand pounds are annually consumed on our coasts, while in Cape Cod Bay alone over 100,000 barrels are turned out of the weirs some seasons and left to decompose on the shores or drift out to sea.

The increased attention paid to the utilization of refuse products of fish in some parts of the United States, especially New England, where not many years ago they were generally thrown away, marks an advance in our industrial life. Every waste product of fish and other aquatic animals resulting from their cleaning, curing, and canning has a commercial value in a crude state or after further manipulation, but in most regions no regard is paid to anything but the actual flesh; and many thousands of dollars are thus annually lost to a class that is least able to afford it. As one instance of the loss our fishing interests are yearly incurring, mention may be made of the economic value of the roe of fishes as an article of food. Practically, the eggs of only two species of fishes—the sturgeon and mullet—are utilized in this country, but there is hardly a fish whose roe is not suitable to be made into a valuable caviar, which could meet with ready sale abroad as well as at home, and would be an important addition to our fishery output, in that it would represent the expenditure of little time and money and the sacrifice of no additional fish. In the utilization and appreciation of our resources we can emulate the Chinese to decided advantage.

Akin to the foregoing topic is the advantage which will accrue to our fisheries through the occupation of new fishing-grounds and the adoption of new appliances for the development of latent resources.

The recent establishment by Texas capitalists of an extensive fishery for red snappers and groupers on the distant offshore banks of the Gulf of Mexico is an important event in the history of our southern fisheries. The advanced policy displayed in having a fleet of sailing vessels remain on the fishing-grounds and in employing steam vessels to take the catch to market affords a suggestive example to the entire country.

The practical experiments made within two or three years and the explorations by the vessels of the U. S. Fish Commission have demonstrated the existence of vast deep-water areas on our coasts which are suitable for the prosecution of beam-trawling and which will yield an almost unlimited supply of excellent fishes which now seldom or never appear in our markets, including a number of flatfishes similar to the most highly esteemed fishes of the European seas.

The adoption of steam propulsion in our ocean food-fish fisheries, as already suggested, may be expected to have a doubly beneficial influence by enabling the fishermen to develop the more remote grounds where fish are likely to be more plentiful, and by relieving the present drain on the inshore waters.

34.—REFORMS AND IMPROVEMENTS SUGGESTED FOR THE FISHERIES OF GREAT BRITAIN AND IRELAND.

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[This valuable paper has been abstracted and arranged by the undersigned, with the consent of Dr. J. Lawrence-Hamilton, partly from articles which have appeared in scientific journals and public prints of Great Britain during the past few years, but chiefly from a privately printed and copyrighted pamphlet, issued in 1890, consisting of a "Report upon the fish markets, fish-trade abuses, and fish supply of the metropolis" and a "Supplementary report upon necessary practical reforms in the fish supply of the United Kingdom." While the work of this author is well known in Europe, where his writings have been extensively circulated and read, the fishing interests of the United States have not generally had his papers brought to their attention. With a view to secure this result, the presentation of this paper to the World's Fisheries Congress was suggested to the author. The paper is full of important deductions, useful suggestions, and interesting information having application to the fisheries of the United States, and will doubtless attract much deserved attention.—HUGH M. SMITH.]

GOVERNMENT FISH INSPECTION.

For the safety and protection of the public it is necessary that Parliament should have fish inspection carried out by efficient government officials, to be appointed to guard over and to protect the interests and health of the public or fish-consumers.

Owing to the general ignorance in detecting fish unfit for food by reason of its decomposition, putrefaction, or poisonous qualities from disease, parasites, and other causes, it would, at any rate for a time, be necessary to appoint special fish-inspectors to examine, seize, and condemn all fish unfit for human food. These official inspectors should be duly trained and competent fish experts, fish naturalists, and fish microscopists familiar with fish diseases and fish parasites, and thoroughly acquainted with the chemical and microscopical characteristics of stale, tainted, decomposed, putrid, and poisonous fish, whether such poisons were normal, occasional, or accidental. A knowledge of the various spawning periods and conditions of fish would be desirable.

Fish markets, fish shops, and stores of fresh, cured, or cooked fish, fish vehicles and barrows and their contents should, when necessary, be inspected. Also fish curing, salting, preserving, bottling, potting, canning, and tinning establishments, wharves, warehouses, stores, etc., specially devoted to storing fish. Fishing smacks and vessels, steam and other fish-carriers, including refrigerator vessels, when necessary, should be inspected. It is, of course, in the interest alike of the public and fish-traders that all premises and appliances in which fish are placed or stored should be kept scrupulously clean, so as to avoid bacterial putrefactive infection. As soon as this economical and sanitary lesson has been learned and appreciated by the public and the fisherfolks, it is to be hoped and expected that fish inspection and fish inspectors will be but very rarely required.

PROHIBITION OF UNBLED AND UNGUTTED FISH IN MARKETS.

Parliament should prohibit unbled or ungutted fish entering any market or retail shop or from being offered or exposed for sale. Prohibiting the sale of unbled or ungutted fish which spoil unspoilt fish in their vicinity would be equally advantageous and profitable both to the fisherfolks and to the public. A small fragment of bad putrefying or putrid fish may destroy whole cargoes or loads of fresh dead fish. The products and bacteria of fish putrefaction are preëminently diffusible, as is shown by the smell of bad fish being so long retained and diffused. Exposing unbled and ungutted fish for sale in markets or shops is, or should be, even under the public-health act of 1875, the carrying on of an offensive trade, with a penalty not exceeding £2 for the first offense, whilst a subsequent conviction may even amount to a fine of £200.

In considering the preservation of fish, its red muscular fibers are comparatively so few that for practical purposes the study of the pale fibers is sufficient. Whilst in the higher animals used as food the muscles are arranged in close, thick, firm bundles of long fibers, in fish nearly all the muscles are in the form of loose, short, soft bundles arranged in narrow rings in a zigzag fashion, separated from each other by delicate partitions of thin connective tissue. Except in the eel, salmon, and mackerel, fat is usually absent in fish. The flesh of salmon yields from 63 to 68 per cent of water, whilst that of ordinary whitefish furnishes from 75 to 82 per cent, which are much larger proportions of water than is contained in meat. Not only in the intestinal tract, but also in the blood, lymph, and tissues of healthy living sea and fresh-water fish, active and multiplying bacteria are found. Though fish up to a certain point apparently are able to tolerate the presence of these bacteria in their blood and lymph, yet, should the vitality of their tissues become lowered by confinement, injury, starvation, or disease, the fish will probably be overcome and die. The same applies to external and internal parasites, which almost invariably frequent healthy fish, which, up to a certain point, are also tolerant of these parasites.

On death, fish readily absorb water from moisture, whether naturally in the atmosphere or foolishly supplied by the custom of using melting ice as well as by the continual watering of fish on the fishmongers' slab. How excessively deleterious the absorption of the moisture will be is apparent upon recollecting the filthy state of the fish boxes, barrels, and baskets in the equally filthy fish boats, fish markets, and some fishmongers' shops.

NEED OF A DEPARTMENT OF FISHERIES AND A ROYAL FISH COMMISSION.

Parliament should create a special department of fisheries, to be presided over by a minister of fisheries, to protect, advance, and develop the fishing industries and trades of the United Kingdom. This is necessary and imperative upon commercial, financial, and economic grounds:

(1) To supervise the production and provision of healthy, fresh, cheap, abundant fish food for the poor and the comparatively poor.

(2) To develop a large foreign and colonial export fish trade.

(3) To gain a knowledge of available fishing-grounds.

(4) To secure and maintain the naval supremacy of our empire from gradually falling into the hands of foreigners by recognition of the fishery marine as the recruiting school of the navy.

I maintain that the fishing industries and trades of the United Kingdom are nationally more important than those of agriculture, which has its representative minister in Parliament. In 1882 it was calculated that already, out of the 60,000 square miles of fish-bearing rivers in England, manufactories and town sewage had so polluted these waters that upwards of one-sixth of these rivers were then no longer able to support fish life. This is an additional reason why national compensation to the fishing industries, in order to cheapen the price of fish to the poor, should be effectively undertaken by Parliament.

I strongly urge upon Parliament to grant a special commission upon fish, fish preservation, fisheries, fish-waste products, fish-hatching, and all allied subjects. I suggest that this proposed royal commission on fish should investigate and report upon the legal, administrative, economical, financial, commercial, trade, and scientific reforms relating to the improvement, development, distribution, and cheapening of the fish supply of the United Kingdom, upon the lines indicated in my report.

THE TREATMENT OF FISH WHEN FIRST CAUGHT.

Very great benefit would accrue to the fisheries by the more general possession of knowledge regarding the best methods to follow in caring for the fish as they are caught. Much avoidable loss annually results to the British fishermen through lack of information on this point. To prepare fish properly for consumption in a fresh condition, they should be killed as quickly as possible.

Immediately on capture, where practicable, fish, prior to the coagulation of its blood, should be gashed under the head, just behind the gills, the usual situation of the heart in most fishes, or else above the tail, which has been the practice from time immemorial in Scandinavia and in Holland; nevertheless British fishermen seem still unwilling to listen to and to learn this wise economical practice. Compared with land animals, fish have but very little blood to lose, and hence fish, on being bled, become at once faint and rapidly pass into insensibility. Next, speedily gut the fish so as to remove its entrails, including the liver and roe. Finally, thoroughly clean each fish inside and outside with abundant washing in clean, fresh-flowing water, sea water being for every class of fish better than spring water. Though gutted fish keep better and longer by the addition of salt or brine into the cavity of the body, I recommend peat moss as being cheaper and much more effective. Universally abundant in Ireland, peat moss should be freely used by its fishermen.

Norwegian fishermen roughly estimate that by bleeding, gilling, and gutting flatfish about one-sixth of the total weight is lost, whilst long fish by bleeding and gutting forfeit about one-fourth of their weight. In spawning fish, being full of roe, these proportions would be materially increased. A codfish weighing 21 pounds is said to have furnished 12 pounds of roe. Thus, especially for railway-borne fish, this economy in freight would mean a great saving to the public—the fish-consumers.

The Dutch, introducing the Scandinavian plans of bleeding, before clotting and gutting, herrings on capture, together with the plan of pickling and curing herrings, reinvented by an Englishman, Will Blenkinson, secured for their countrymen from the fourteenth to the eighteenth centuries the virtual monopoly of the marine mastership of the world, including its carrying and export commerce. Though fish is preëminently more prone to early putrefaction than meat, nevertheless the conventional British fish markets and many fishmongers' shops stink from avoidable causes, and thereby spoil any unspoilt fish in their vicinity. A slaughter-house would be properly objected to in the heart of most towns, nevertheless fish markets and fishmongers' shops, evil-smelling from avoidable putrefactive bacteria, are sanctioned by indolent custom, though I presume that under the health acts of the United Kingdom their present condition is illegal.

Chiefly owing to being bled on capture prior to the clotting of the blood, Swedish and Dutch herrings are abroad gradually excluding Scottish herrings, which are less carefully cured and selected than the Scandinavian and Dutch herrings.

Modern science confirms the view that putrescent changes occur more rapidly in blood and other body fluids than in muscle and fat by the microscope so frequently revealing putrefactive germs or bacteria or microbes in the blood and internal fluids of fish, flesh, and fowl, whilst their muscles and fat may still be quite healthy. When the blood becomes contaminated with these putrefactive germs it is likely to at once infect the sound flesh, muscle, and fat. Indeed, in preserving all animal substances it is advisable to keep them as dry as possible, which is the principal factor in curing, salting, or smoking fish or meat. Handling fish or meats tends always to accelerate and often to invite and start putrefaction. In the frozen-meat trade, not alone is the carcass kept hard-frozen and dry, but it is invariably covered with a stout sack or shirt to prevent dirt, by handling or other means, injuring the meat. Hence fish, freshly captured and placed on their bellies upon the too-frequently filthy board at the bottom of the fishing smack, will often have their bellies rotten whilst their sides and back remain comparatively sound. Other conditions and circumstances being equal, it is found that fish, flesh, and fowl keep in proportion to the length, density, compactness, and hardness of the microscopic fibers which unite together in bundles to form the muscle. Fat, of course, keeps much longer good than muscle, whilst moisture, high temperatures, and exposure to the direct rays of the sun hasten decomposition. Over-driven cattle, and fish drowned in the meshes of the nets, as well as all animals whose strength has been exhausted by the chase or previous privation or disease, are prone to decompose with increased rapidity. This tendency to rapid putrefaction after death has been observed, by army doctors, in troops who have died on the battle-field after long fasting, fatigue, and fighting.

TORTURING AND STARVING FISH.

Fisherfolk waste fish by starving and torturing. In the United Kingdom those professionally and pecuniarily interested and engaged in fish torturing and starving have, in the ignorant thoughtlessness of chronic custom, been alike blinded to the sacred civilizing duties of humanity and Christianity, and have also overlooked and omitted their own material profits and advantages. Fish starving is a domestic sport which diminishes the commercial value of the fish; it ruins the flesh, flavor, and firmness of the fish; it tends to induce parasitic, bacterial, and other diseases in the fish; it diminishes the weight of the fish, and increases its cost both to the professional fish-starver and to the consumer—the general public. Fish so starved are more liable to rapid decomposition soon after death, and in codfish such starved fish are more difficult to crimp, which are additional causes and circumstances tending to enhance the avoidable risks of the present fish trade, and therefore an unfair tax on the consumer. The average absolute loss in weight of codfish by starvation and imprisonment appears to represent 10 per cent of the entire weight of the natural normal healthy fish, a heavy avoidable commercial loss. The close confinement of codfish in their fish chests sunk in the fish docks causes a rapid increase in the relative number of bacteria alleged to be always present in the blood of living fish. When the proportion of bacteria exceeds that which the blood of living fish can tolerate, then the fish commence to sicken and will often die, even if well and regularly fed in a fair amount of space, as in fish kept in aquaria. Hence these sunk fish trunks become the rapid carriers of contagious disease to any healthy fish which may chance to be in or near the fish chest.

In addition to tolerating in health a certain proportion of bacteria, fish are also, up to a certain point, equally tolerant of various external and internal parasites; and generally every fish dissected shows either some parasites, as tapeworms, in its intestines, or other parasites about its gills, eyes, skin, or elsewhere, and even sometimes as many as fifteen different species of parasites have been discovered in one individual fish. Often these parasites, along with the bacteria, increase so as to gain the battle over the fish, especially when the latter becomes weakened by starvation, confinement, injury, or other causes tending to diminish its vitality. Parasites also promote decomposition the moment the fish dies. These sunk fish chests never err on the side of cleanliness, and are hence favored localities for hatching and breeding bacteria and parasites specially destructive to fish health and fish life. The loss of life in codfish caught in the nets will not average upwards of 5 per cent. Hooked fish on being drawn up are liable to disgorge or vomit, not alone the contents of their stomachs, but also, especially in the case of deep-sea and abyssal fishes, to have their stomach and part of their intestines protruded through their mouths. Having air-bladders, deep-sea and abyssal fish by the rapid altered pressure, together with the influence of shock, get their air-bladders so dilated with evolved gases that they are unable to sink from the surface of the water in welled smacks till the fisherman, passing a long needle through the walls of the fish's abdomen, or the pit of the left pectoral fin, by letting the gases escape, allows the fish to resume its natural habits. Hooked salmon vomit through fright alone. Fish may be sometimes seen with a prolapsed and protruded rectum and lower intestine, which appears to be due to relaxed flabby muscles, and is a sign which very shortly precedes the commencement of decomposition. As a rule hooked fish keep longer fresh than netted fish, which, owing to being injured by having been trawled over rough grounds, together with the sharp prolonged squeezing and banging about they get in the nets, are specially liable to early decomposition.

Much of the so-called best prime "live" codfish at Billingsgate has after capture been transferred into welled smacks which accommodate from about 600 to 1,000 codfish, each weighing from 16 to 20 pounds avoirdupois. Especially in rough weather, after having been subjected for a few days to injury, confinement, and starvation in the welled boats, to prevent these fish from eating one another they are sometimes specially secured by their tails. On arriving in port some 40 of these codfish are tightly crammed into a fish chest, sunk in the fish dock (which in England answers only during the cold weather from about November till April), where the codfish, after further confinement and starvation, all die within a few weeks. If the fish be kept for a shorter interval, say, a fortnight, then on an average only about 10 per cent of such codfish are found dead upon opening the raised chest. All such starved, closely confined codfish lose much of their natural healthy flavor, firmness, weight, and plumpness. The fish, having to support life, consume much of the substance of their own livers, which appear small and shrunk when compared with the normal liver of a freshly killed healthy fish. This codfish, if not previously dead, is then stunned with a blow from a big mallet, and thus, whilst insensible, crimping is alleged to be carried on. As the sensibility never returns there is practically no cruelty. Skate are said sometimes whilst still alive to be crimped by fishmongers. So long as cod will "crimp" or show muscular contraction it is called in the fish trade "live cod," an intentional misrepresentation. Out of its healthy season, a woolly, watery codfish is often appropriately termed by the fishermen "churchyard" cod. Recollecting these facts, the familiar dry, flabby, cottony taste of the vaunted best prime "live" codfish so often sold at Billingsgate and elsewhere is easily explained. Skinning live eels and gutting live fish, causing avoidable, useless torture, are occasionally practiced.

In welled boats halibuts are hung up by their tails, under the delusion that in these artificial conditions the fish will enjoy longer lives and that their flesh will keep better fresh for the market. These local injuries often actually cut through the soft parts till the bone is exposed. As to the "alleged habits of halibuts at the bottom of the sea, arranged in parallel rows, waiting and watching for small fish and shellfish: when failing such food supplies, the hungry halibut attacks and eats the tail of its nearest neighbor, which explains the frequently injured and absent tail of freshly caught halibut." This tail cannibalism on the part of the halibut is an absurd invention to hide the cruelties practiced in welled smacks.

Lobsters and crabs are often kept alive on wet seaweed or ferns, and live on an average in hampers for a couple of days, starving before they reach the fishmonger, who frequently stores them, if not sold, till they die of starvation. Lobsters and crabs thus starved to death lose weight, firmness, taste, and flavor, and immediately on death tend to decompose rapidly, which in such conditions is but slightly diminished by boiling in salted water. Instead of puncturing with a stiletto, wriggled about so as to break up the animal's brain material, and then plunging the crabs and lobsters into boiling water, out of sheer thoughtlessness and careless custom living lobsters have been placed in cold water which, while it is being heated up to the boiling point, causes the animal prolonged avoidable torture, for if plunged into boiling water it quickly dies. Previously to boiling, to rid them of sand and dirt, crabs and lobsters should be well washed in fresh flowing water. Spanish fishermen catch a coast crab only to cut off the good-eating coveted claws, and then return the mutilated animal to the sea, to be recaptured if possible upon the reappearance of its developed claws.

Immediately before its death fishermen scale the red mullet to induce permanent contraction of its superficial pigment cells, causing the fish to become the intense popular red color of the trade.

Although no fish or shellfish is legally protected against cruelty in this country, and although it is not punishable to boil fish alive, to roast fish alive, to slice fish alive (as turtle used to be in Ceylon, and as some air-breathing fish carried about in earthen pots in China are still), yet it is to be expected that these cruelties will rapidly disappear as soon as fish-traders find that humanity to animals will benefit their own pockets. Codfish will keep in excellent health and condition if placed in artificial ponds or docks, fed with sea water, as was the custom among the ancient Romans and ancient Egyptians. The present St. Petersburg fish farms or ponds, fed by the river Neva, and where each species of fish has a separate compartment, yield profitable rentals. Lobsters and crabs can be fed on almost any fish refuse.

AVOIDABLE FISH-SPOILING THROUGH CARELESSNESS, FILTH, AND BAD PACKING.

Placed upon their bellies on the usually filthy boards at the bottom of the smack, the abdomen of the fish may rot whilst its sides and back remain comparatively sound. In the United Kingdom captured fish are often thrown unbled and ungutted, and always unpithed, into the more or less foul hold of the fishing boat, where they remain exposed to successive alterations of heat, sunshine, moist and melting ice, and putrefactive filth. The fish are frequently ruthlessly crushed, bruised, and cut by the heavy weights of their thoughtless captors standing in sharp-nailed boots, whilst the lower layers of fish may have tons of fish resting upon them. In some parts of England, from about September till April, many of the smacks fish by themselves, and not in a fleet from which a steamer or other carrier takes away each day's fish. As such isolated smacks stay out at sea about a week, it follows that a portion of their catch has been already some six days in ice before landing. Such stale fish by putrefactive contagion damage the fish more recently caught. On reaching the harbor the fish are commonly pressed into filthy fish boxes, barrels, and baskets pregnant with putrefactive bacteria. The fish suffer further shaking, banging, and bruising by being flung about on the pier, where this food lies again exposed to heat, rain, and sunshine. As the fish boxes or trunks have always wide-open apertures, and in the carrying boats and railway and street vans the boxes are closely piled one above the other, it follows that the flowing filth from the upper boxes circulates through the lower ones, whilst the last tier, both from above and below, is surrounded with these putrefactive abominations.

Fish are, again, further damaged by close packing and pressure. To economize space in packing the barrels a sharp sudden wrench or twist bends the fish into a coil, breaking up the animal's softened muscles and structures, thereby inviting and increasing putrefaction. Finally, such fish are tightly crammed into rough, porous, unvarnished, foul boxes and barrels, which are rudely closed by sharp hammering.

The practice of suddenly twisting the tail of the whiting, and passing it through its mouth or through the sockets whence the eyes have been removed, ruptures the soft, flabby, loose, muscular fibers, especially when such fish have been previously skinned. The exposure of dead fish thus wastefully maltreated in fishmonger's shops, pregnant with putrefactive bacteria, accelerates decomposition.

When fish has once become flabby, stale, or tainted no preservative process can possibly restore its lost flavor, freshness, or firmness.

The fish which British fishermen occasionally gut are often to be seen placed in a few inches of stagnant water supersaturated with putrid blood and filth. Frequently handling fish, especially with dirty hands, accelerates putrefaction, as also the time-honored custom of watering fish on the fishmonger's slab. By a statute of Edward I., dated 1272, no fishmonger was allowed to water his fish more than once; no fresh fish was to be kept in London beyond the second day from its capture; nor was any bad fish to be sold. The profit of the London fishmonger was limited by this statute to one penny in the shilling.

Fisherfolk so fully realize the present difficulty of preserving fish that stale and decomposed fish is technically termed "overday" (over-a-day) fish. Fisherfolk say that thunderstorms spoil fish, but as thunderstorms occur chiefly in hot, still weather, associated with rain, the explanation is included in the fact that fish decompose quicker on a wet windless winter's day than during a dry hot summer's day with a brisk breeze. Others credit the bright rays of a full clear moon with causing rapid decomposition of freshly caught fish; but there seems to be no foundation for this statement.

INEFFICACY AND INJURY OF CHEMICAL PRESERVATIVES.

Common salt, brine, boracic acid, tartaric acid, niter, sugar, burning sulphur and aromatics, boro-glyceride, limewater, shea or vegetable butter, powdered charcoal, flour, sawdust, or antiseptics, as well as forcing under mechanical pressure chemical solutions into fresh fish, alike fail to keep fish from decomposing when applied in the usual commercial proportions. Chemicals which "preserve" fresh food injure digestion. Hence the employment of all such chemicals in fresh food should be illegal.

The medical and chemical professions should unanimously protest against the introduction of chemicals into fresh food. Of course salting, drying, curing, smoking, preserving in oil, pickles, vinegar, mustard, sugar, spices, alcohol, and other familiar methods of household cookery are not to be included in the term chemicals. Practically, "preservatives" like boric acid and a host of other public and secret methods are rarely used till the "fresh" food is more or less "on the go"; that is to say, till the first stage of decomposition has set in. This trade trick is an old dodge to hide the tainted taste of stale provisions.

THE FAILURE OF ICE AS A PRESERVATIVE AGENT.

The thickness of fishes and certain qualities of their skin cause slight variations in the freezing-point of the different kinds. The freezing-point of fish is a few degrees below that of water or the ordinary commercial ice at 32 F., which, even were it used in large excess, could then only superficially and incompletely chill the exterior layers without practically affecting the temperature of the interior of a thick fish's body. In all conditions and circumstances ice spoils the freshness, firmness, and flavor of fish by rendering it, prior to putrefaction, insipid, soft, and flabby.

Supplying moisture, ice circulates the filth contained in the foul fish trunks. In the United Kingdom, by coasting vessels, fishing is seldom carried on during Saturday afternoon or on Sunday; fish caught on Friday night and often days previously, especially during continued storms, fogs, and calms, could not reach Billingsgate till Monday morning, and the consumer late on Monday, when it would never be less than three days old and often more. Trawlers sometimes stay out at sea for ten days or more at a time, icing their fish as they catch it, and only return to land their fish on the exhaustion of their supply of ice. Indeed, much of the best prime trawl-caught fish sold at Billingsgate is from 3 to 10 days old. The London fish trade alone is now (1889) said to consume upwards of 1,000 tons daily of ice during the summer months.

Ice is an expensive, bulky, rapidly perishable, wasteful product. The present (1889) average wholesale winter or minimum price of rough artificial ice is as low as 11*s*. the ton when purchased in quantities of 2 tons or more, and the average price of artificial ice in winter bought by the smaller fishmongers and costermongers is 1*s*. the cwt., or at the rate of £1 the ton. Even in winter, in London the price of natural Norwegian ice is often £1 10*s*. the ton, which is popular in Billingsgate and other fish markets, where also actually crushed natural ice at 1*s*. 9*d*. the cwt., or £1 15*s*. the ton, is customary. Being imported from the metropolis, ice in most fishing districts is, again, much dearer than in London. Compared with the winter prices, during the summer months, when ice is most used and most wasteful, it is much dearer—sometimes by 50 per cent.

Experience seems to show that the gravest cases of fish poisoning arise more commonly from eating fish which has been iced than from eating fish kept naturally cool and dry. Where fish is iced it appears that the ice only favors putrefaction by furnishing a constant supply of moisture carrying with it the putrefactive bacteria derived from its foul surroundings, so that this iced fish remains covered with fresh solutions of filth pregnant with putrefactive bacteria. Thus large quantities of those subtle complex bodies, the animal alkaloids or ptomaines, are probably elaborated and give rise to marked symptoms of poisoning which sometimes occur from eating iced fish. On the other hand, keeping fish dry and cool can in no way favor putrefaction. And although here cases of poisoning may happen, yet, as far as I can gather, the symptoms are much less serious and go off sooner, the toxic or poisonous effects being usually confined to a passing attack of vomiting and diarrhea; whilst in the case of iced fish the vomiting and diarrhea may be less marked, though the other symptoms may be much more profound and lasting, and sometimes even fatal.

THE ADVANTAGES OF DRY-AIR REFRIGERATION.

Apart from its present high prices, fish is but comparatively little eaten in the United Kingdom, because it seldom reaches the consumer until it is more or less spoilt, whilst English meat is usually of excellent quality and condition.

To obtain an imperishable, cheap, healthy, and abundant supply of fish food, it is necessary to bleed, gut, and clean the fish at once on capture, and forthwith transfer it to the dry-cold-air refrigerator chambers of special steamers at the fishing-grounds. This hard-frozen fresh fish should be distributed to the fish markets, wharves, and stores situated on canals and rivers by dry-air refrigerator barges, or insulated covered barges for shorter distances, whilst seaport towns could receive the fish direct from the refrigerator steamers, as well as towns like London having wide and deep rivers. As far as possible all railways should be avoided. In the United Kingdom their extortionate rates for the carriage of fish have oppressed the fish trades to the special injury of the poor. However, if frozen fish has to be sent long distances by rail to towns unprovided with canals, rivers, or lakes, as in some of the American cities, then special refrigerator railway fish cars are advisable.

Fresh food is kept imperishable and healthy only by regulating the temperature so that the bacteria of putrefaction and their complex products can not exist. Vegetable and animal foods at low temperatures remain imperishable, provided always that all available moisture is excluded. Meat, game, poultry, and fish must be thoroughly bled before blood-clotting, then gutted and cleaned. Before being artificially cooled or refrigerated, flesh must gradually give up its animal heat, its excess of moisture, and complete the rigor mortis. In arctic climates killed animals, if unbled and ungutted and not previously gradually cooled, may be hard frozen outside and putrid internally. Thus, much refrigerated meat, etc., have been spoilt by omitting to let off the excess of its animal heat and its rigor mortis ("setting" or "firming" in meat, "stiffening" in fish) prior to artificial cooling or refrigeration.

In Russian winters fish is naturally frozen for months, and is sawn for the retail customer. Fish is kept frozen naturally by the dry, cold winter air, in the Hudson

Bay territories, in the elevated regions of Thibet, and in Arctic winter climates generally. The frozen-meat ships, for a forty-five days' passage from London to New Zealand, keep fish frozen for their passengers' food, though usually omitting to have such fish previously bled and gutted. For years the Hudson Bay Company shipped frozen salmon (though unbled and ungutted) to London, Australia, New Zealand, etc., but now the Canadians find that it pays them better to deal with the United States. Frozen salmon brought from Labrador in the screw steamer *Diana* kept good for 200 days, whilst in the Canadian Court of the 1883 London Fisheries Exhibition, frozen salmon after eighteen months of such treatment was found to be excellent eating. A frozen-fish trade is carried on between Senegambia, in West Africa, and Marseilles.

By means of a mixture of ice and salt a large, remunerative trade in hard-frozen fresh fish has long been successfully conducted in the United States, where refrigerator steamers fetch fresh fish from the fishing-grounds, freeze it hard, store it as long as required in specially constructed insulated refrigerator wharves and warehouses, and, when necessary, deliver it frozen in specially constructed fish refrigerator railway cars to inland distant districts unprovided with canals, rivers, or lakes. However, this salt and ice process is much dearer than the dry-cold-air methods.

By the introduction of frozen fish, both the fishermen and the fish-venders themselves will be great gainers, as with an extended commerce they will cease to deal in a perishable product, and also no longer require to waste their money on ice. In time every large town or district will require its own refrigerator stores or depots where both frozen fish and meat could be preserved to supply the local traders, who would thus never have to suffer pecuniary loss from overstocking with perishable food.

Excluding the wholesale fresh salmon trade, almost a monopoly, I estimate that, including all freights, costs, and charges, the wholesale selling price of fresh fish in the markets of the United Kingdom now (1889) already exceeds £15,500,000 a year. But by judiciously pushing and developing the dry-air frozen fresh-fish trades this wholesale commerce for home and export consumption could in a few years be made to exceed £100,000,000 a year. It would be a national disaster if foreign competition were to secure such a trade, which, in addition to its financial aspect, includes the best school in which to train sailors for our navy, a fact long recognized by the Dutch and French.

The poor are naturally puzzled, perplexed, and frightened at the present ever varying and fluctuating prices of the same kind of fish under the existing wasteful fish-destroying systems; this is another reason why they will welcome the advent of frozen fish. The total supply of frozen fish will be quite independent of local fogs, storms, calms, and the catch of the preceding twenty-four hours. Frozen fish should therefore remain all through the year at constant prices.

THE APPLICATION OF REFRIGERATION TO BAIT PRESERVATION.

The scarcity and high price of bait at times can doubtless be largely overcome through the use of refrigerators on vessels and on shore. Whether fish and other aquatic animals are to be eaten by man or preserved as bait with which to catch fish, the methods of preserving such animal tissue must be scientifically and industrially the same. Hence, upon the lines I have already explained, dry-air refrigeration is the only rational, reasonable, and economical plan to preserve fish baits. Therefore, except dry cold air, all chemical or other antiseptics, as used in the diluted proportions practicable, have and will always fail, as foreign and home investigations and experiments have conclusively demonstrated.

Where bait has to be used alive, then it must be preserved in the same manner previously herein advocated.

One of the many useful trade functions to be fulfilled by the proposed free technical schools, would be instructions how at all times to provide abundant cheap bait for fisherfolks, who are now often unable to go out fishing because of fresh-bait famines. This is another avoidable factor tending to make our present fish supply dear, scarce, and bad, whilst inflicting an avoidable though severe loss upon too many of our impoverished fisherfolks and their families.

DRY-AIR REFRIGERATORS FOR VESSELS, MARKETS, ETC.

It is only quite recently that the dry-air machinery for ships, wharves, warehouses, and railway cars has been sufficiently perfected to work well, cheaply, and regularly, so as to be commercially remunerative. Hence the first losses of the earlier introducers of the frozen-food trades are now avoidable. It is to be expected that in the near future further improvements in the economy and efficiency of the frozen-food trades will be introduced, though already, at home and abroad, several rival plans and patents compete for business. Setting aside minor details, the best processes for food freezing may be thus briefly summarized. The average temperature of the cold air in the special ships and storehouses is turned on at 70° to 80° below the zero of Fahrenheit, or upwards of 100° F. of frost. For meat the cold in these refrigerator chambers can be accurately regulated by the machinery, which usually keeps the chamber at 16° to 22° F., though in the case of fish a less amount of cold is necessary. For this purpose the air to be cooled is so greatly compressed that its temperature becomes elevated to about 240° F. The heated air then passes through a long series of pipes, surrounded by cold water, which absorbs the heat of the compressed air, bringing this air down to the temperature of the cool water. This air is next let into another vessel surrounded with cold air, where it deposits all its moisture, for it is essential that the air for freezing food should be freed from every trace of water or moisture. By this time the doctored and dried air has become cooled to about 70° F., when it is suddenly and rapidly expanded, and thereby becomes so intensely cold that the air passes out of the machine at a temperature between 70° and 80° below zero, Fahrenheit, or upwards of 100 degrees of frost. This dry cold air circulates through the refrigerator chambers, and afterwards returns to the compressor machinery, to be again further dried and cooled down to 70° or 80° below zero.

The refrigerator chambers have walls, floors, and ceilings, composed of several layers of nonconducting or insulating materials, generally charcoal, with specially constructed massive insulated doors, so as to hermetically seal the refrigerator compartments. Here the substitution of peat moss for charcoal would be an economy.

Some frozen meat removed from the refrigerator ship *Tainui* to a covered insulated barge maintained 3° of frost after 55 hours, although after the first 24 hours had elapsed about half the frozen carcasses were withdrawn.

For carrying fish from the fishing fleets at the fishing-grounds, specially constructed coal-saving refrigerator swift steel steamers, of about 200 to 300 tons each, would be advisable. The present frozen-meat ships have chambers insulated with thick layers of charcoal, though peat moss would be more economical and efficient, whilst in case of repairs from accidents, peat moss is much cleaner and weighs less than charcoal. In storing hard-frozen fish, as far as practicable leave an air space around each big fish, whilst large valuable fish, like meat carcasses, are best kept clean and undamaged by a separate canvas shirt or sack. Small fish can be packed in layers of peat moss.

REQUIREMENTS FOR A SANITARY FISH MARKET.

It is essential that the entire premises used for fish-storing should be constructed of glazed, polished, or enameled, level-faced, non-absorbent, non-porous structures and materials; marble, granite, or artificial "stones," highly polished; glazed bricks or glazed tiles; stout, hard, smooth glass; enameled slate or enameled metals for walls, ceilings, fittings, and fish slabs. Fish markets should have roofs of glass and metal only. Supports for the stands can be made of highly-polished or enameled metal, best circular or tubular in form, so as to avoid edges, ridges, and corners, which act as traps or dust bins to collect dirt and dust and breed therein contagious putrefactive bacteria to spoil unspoilt fish. The flooring or pavement should be even, non-porous, non-absorbent, hard, but not too slippery. In public markets a good gradient or fall towards the gutters and outlets is necessary for cleansing and disinfecting purposes.

To exclude contagious putrefactive bacteria, absolute cleanliness, dryness, and low temperature are imperative. If fish were bled before blood-clotting, immediately gutted, cleaned inside and outside with abundant water, especially sea water, and then dry-cold-air refrigerated, these processes would dispense with the expense of ice and disinfectants. Ungutted fish degrades a fish market or fish shop into an offal or filth store. It is as unjustifiable an abomination as an "uncleaned" or ungutted meat carcass, which no "butcher" would tolerate in his shop. By butcher I mean meat vender, who always keeps his slaughter and offal house apart and away from his shop. Fishmongers and fish salesmen should do likewise.

Besides the avoidable Billingsgate bouquet, the number of flies and blue-bottles in warm weather found in fish stores often roughly indicate the amount of avoidable filth and decomposing fish stored in and about the premises. The penetrating odor of bad fish and fish refuse usually prevents the fishmonger being able to let off profitably, if at all, the upper unused parts of his house. Being a local nuisance to the immediate neighbors, some landlords decline to let to fishmongers, while other landlords make many a poor fishmonger pay increased rent, which entails increased rates and taxes on the struggling tenant.

For economical advantages cold dry air and electric light are used in many large wholesale meat stores and shops. Such conditions are alike applicable for storing fish at sea or on land. The burning of gas evolves moisture, heat, and carbonic acid, besides some carbonic oxide, sulphurous acid, sulphureted hydrogen, ammonia, etc., which in crowded market-places, added to the impure products given off by continual excessive respiration and perspiration, contaminate and vitiate a limited supply of air, especially damp air and fogs. These, together with the dirt brought in from the streets and stables sticking to the boots of the market crowds, which mud and filth necessarily adheres to its pavement, are all united conditions and circumstances further favoring the rapid decomposition of unspoilt, spoiling, and spoilt fish. Hence to diminish these evils large public fish markets should be supplied with electric light. Gas should be in readiness in event of the electric light being out of order or during the engineer's accidental absence, etc.

UTILIZATION OF WASTE FISH AND FISH PRODUCTS.

The alarming, augmenting, and avoidable waste of fish and of products made or derivable from fish and fish refuse, together with the waste of immature and of unsalable fish, are questions of national importance. Confirmed by chronic conventional careless custom, these causes combined increase the cost and charges paid for by the consumer and inflict a cruel commercial loss upon the fish-catchers. In trawling, the net is often brought up without containing a single salable fish. Whether the unsalable fish amounts to 50 or 500 per cent, or even more, as compared with the salable fish is a subject upon which fishermen are proverbially reticent. When they do give information on this point their evidence is so opposite and contradictory that the solution of this topic is not thereby advanced. However, when coasting smacks unavoidably catch nothing better than immature and other unmarketable fish, under a rational economic system this fish should be used up for the manufacture of waste products, which in the United States of America represent upwards of 14 per cent of the total value of their fisheries. Excluding the waste of immature and unmarketable fish, I estimate that upwards of £2,156,900 a year is wasted in the United Kingdom by omitting to work up the waste products of fish after the American methods.

Owing to pressure and other causes, almost all fish caught in the nets are either dying or dead before they are landed into the smacks. British fishermen frequently throw immature and unsalable fish and fish refuse into the sea. From time immemorial the Chinese and Japanese have profitably worked up and economized the waste products of fish. The Americans boil fish to extract the oil useless for manure, while the bones are made into glue and other commercial products, and the remainder is used as manure. The Americans bone and skin their codfish and pack it in tins; while thus making a higher-priced article, they derive extra profit by working up the skins and bones for by-products.

In the United Kingdom valuable waste products derivable from fish refuse are usually ignored in every household. Excellent stock or basis for soups can be made from the heads, bones, skins of fish, and of filleted fish, a familiar economy in China, where to make gelatine soup even sharks' fins often fetch thirteen pence a pound. The fins of sharks, rays, and dogfish yield good isinglass—a product universally neglected by our fishermen. A bread of fish "flour" is popular in some countries. English rays are imported into France for making soup; bone earth from fish refuse for manure; albumen from fish blood. A "meat" extract is made from fish; it has no fishy flavor and is alleged to be better and cheaper than beef extracts. This fish extract mixed up with pea food, flavored with herbs and salt, makes a good food sausage. Herring meal, mixed with starchy food, affords an economical and excellent food for cows, without giving any fishy flavor to their milk. In some foreign countries domestic animals and poultry are fattened on fish.

The heads, fins, entrails, blood, etc., give good guano. The skins and bones of fish supply strong adhesive cement. The dried skins of the shark, dogfish, ray, etc., are useful for polishing wood and ivory, and in Egypt serve for the soles of shoes. These fish skins furnish a kind of leather called shagreen. The dried skins of flatfish can be used for gloves, for "leather" purses, for clarifying coffee, as a substitute for isinglass, and for artificial baits. The Chinese use painted and varnished fish skins as ornamental lanterns. In Japan, wax is made from the skins and intestines of fish. Eel skins serve for whip thongs, and when dressed and dried make braces. In America, cusk and torsk skins have been patented for shoe leather. Siberian peasants clean, stretch, and dry the skin of the fresh-water burbot for leather bags and as a substitute for glass window panes. In some parts of Asia the tanned salmon skin supplies a prettily marked scale-like leather and ray skins a good imitation of morocco. Sham porpoise leather is made from the skins of the seal, walrus, and white whale. The American whitefish yield large good upper leather. India ink is obtained from the cuttle or sepia fish. The mullet's roe provides the botargo of Italy and is an ingredient in Indian curries. Besides the sturgeon, the roes of many other fish furnish caviares.

On capturing fish, the fishermen should squeeze the ripe roes and milts of the same species of fish into a clean bucket of fresh sea water. Thus fertilization of the eggs would be cheaply secured. The bucket would then have its contents returned into the ocean. By technical education, as soon as the fisherfolks realized the advantages of thus adding largely to their marine animal populations, it is to be anticipated that such ready and rapid egg fertilization might in time become a usual practice. Especially about the middle of February the decks of boats where codfish are killed are actually milk-white with cod spawn, which should be used for artificially rearing codfish, as in Norway. Russian scientists have been specially successful in rearing fish from the roes of recently dead male and female fish.

Mussels, one of the best baits for sea fish, have often been destroyed to serve as a cheap manure.

Oyster shells are reported to make good "metal" for roads, and have been used to fill up the foundations of buildings and railway embankments; also as ballast for vessels, manure, food for poultry, and as lime in certain cements. However, oyster shells are most profitably employed in the cultivated oyster farms, so that the oyster spat or eggs can attach themselves to the ready-made attractive home of the old oyster shell. In Russia a brilliant white-wash paint is made from oyster shells. It is said that from these shells the ancient Japanese formerly made luminous pictures to appear at night time, and which mysteriously disappeared during daylight. I am informed that this is one of the many lost arts of past history, and, like that of manufacturing the famous Tyrian purple from the murex or purple-snail, has unfortunately been allowed to die out, perhaps because aniline dyes are cheaper.

FREE TECHNICAL SCHOOLS FOR FISHERFOLKS.

Occasional trade or technical free educational and training schools for fishermen, fisherfolks, and fish-curers should be provided by the legislature in suitable situations. These schools would be a national economy and prevent or check wasting fish food and fish products, tending thus to diminish the price of fish to the consumer, and remove much of the fisherfolks' chronic financial distress. Fish would soon become a uniformly fresh, healthy, cheap, abundant food, and, being sold in a frozen condition, it would practically be an imperishable article, as I shall subsequently show.

Within the last twenty years the construction of fishing boats has much improved, as well as the appliances for catching fish. Since about 1850 the varied combined applications of chemistry, engineering, and mechanics have revolutionized and advanced agriculture. Nevertheless the average fisherman of the United Kingdom seems generally to be a mere primitive fish-catcher, like the savage of present and bygone times, ignorant how to treat and store caught fish. This is not the fault of the British fisherman, but is owing to his political and social misery and misfortune.

In fishing districts and villages he has no opportunities afforded him to learn the practical technical rudiments of his own calling, any more than his means would enable him to study physiology, zoölogy, chemistry, and mechanics at the distant universities.

As regards the first experimental technical free school for fisherfolks, some suitable site or sites in or near Brighton appear to be one of the most desirable localities in England. Its vicinity to the harbors of Newhaven and Shoreham (whilst at least one of its piers could be transformed into a good fish market), its own resident population of upwards of 150,000 persons, its unequaled, easy, and cheap approach by rail or road to London, preëminently recommend Brighton as a fit center for training and educating fisherfolks and fish-curers. The Brighton aquarium—built, as I am informed, at an expense of upwards of £130,000, and being the largest in the kingdom—offers unequaled opportunities for the study and observation of living aquatic animals, including experimental artificial fish-hatching. The Brighton Museum contains already numerous appropriate marine specimens, whilst its adjoining free public library and reading rooms would afford technical facilities.

The legislature should supply some suitable steam trawlers of about 200 to 300 tons each, with dry-air refrigerator machinery fitted with dry-air stores, to be at the disposal of the proposed Fisherfolks' Free Technical School. Thus fisherfolks, including fish-curers, could be practically taught and trained at sea the varied work of their callings. At least one vessel arranged for carrying on practical industrial technical laboratory work in reference to live-fish preservation, fish-hatching, dredging for marine specimens, and allied topics should be also provided and equipped by the legislature. Such a vessel, by means of electric lights and divers, might obtain much valuable information as to many marine problems connected with the food, habits, and breeding of marine animals.

In reference to these subjects and investigations, at a truly trifling cost, the stationary light-house ships would often make admirable marine laboratories where fisherfolks could learn many useful matters. The proposed Fisherfolks' Free Technical Schools for the United Kingdom, acting in coöperation with the Marine Biological Associations, with the Scottish and Irish Fishery Boards, and similar institutions, would, doubtless, with sufficient funds, do great and good work, so as to improve, increase, and cheapen the fish supply and to commercially develop the now decaying fishing trades and industries of the United Kingdom, India, and our colonies.

Among the lines of study and practical instruction suggested for the curriculum of the training schools, are the following:

1. Course in swimming, floating, diving; resuscitation of apparently drowned persons; best means to extinguish fire and to save life from suffocation, burns, and scalds; the use of life-saving apparatus; the use of oil in rough, stormy seas.

2. The management, breeding, and training of carrier pigeons for postal purposes between sea and land, to save life and property and for commercial purposes.

3. The manufacture, preservation, drying, and mending of fishing appliances; the repairing of sails, oars, boats, and vessels at sea, in harbor, and on shore; the use of signals, lights, buoys, fog-horns, etc.

4. The preservation of fish at sea, by immediate bleeding, gutting, and washing; the treatment and utilization on board ship of fish refuse; dry-air refrigeration; packing; cleanliness and inspection of fishing vessels; preservation and transportation of live fish and other aquatic animals for food and bait.

5. Elementary practical teaching of deep-sea dredging and specimen collecting; sounding, to determine nature of sea bottom and probable character of fish; use of collecting tanks for live and museum specimens; preservation of fish and other aquatic animals and plants for local museums; observations of the habits and growth of fishes, etc., in nature and in aquaria.

6. Preparation of fish by drying, smoking, salting, canning, etc.; preparation of oils, extracts, fish meal, manures, etc.; cooking of fish; determination of edible qualities of fishery products now little used or neglected.

7. Fish-culture; mutual relations of inland fishing, farming, and forestry; studies of methods in other countries.

8. Storing, transportation, and distribution of fish; construction of fish markets, stores, vehicles; construction of refrigerators, refrigerator cars.

9. Comparative rudimentary anatomy and physiology of typical aquatic animals and plants; their diseases and parasites.

10. Consideration of questions concerning the fisheries.

11. Fish inspection; naked eye, chemical and microscopical detection of unwholesome fish; detection of trade frauds, substitutions, and adulterations.

CARRIER-PIGEON AND TELEGRAPHIC SERVICE FOR THE SEA FISHERIES.

Fishing fleets should signal by means of carrier pigeons for the refrigerator steamers to come out from the harbors to remove the catch. These carrier pigeons, dispatched at intervals, especially if repeated to allow for accidents, would be useful to the smacks in case of accident and distress, and could also be employed by the fishermen to send messages, weighing up to 2 ounces, to the steamers, as giving orders to bring out any articles required by the fishermen, including food, medicines, fishing nets, tackle, bait, and other requisites.

Alighting on the platform of the pigeon-house, connected with an electric bell for day and uncovering a colored light for night work, the pigeon announces its own arrival. At a trifling cost fishermen and sailors would soon learn to train and breed these carrier pigeons. After a while, probably, no fishing smack would put to sea without a few carrier pigeons.

To effectively encourage fishermen to carefully and extensively rear, train, and breed these carrier pigeons, the Admiralty and the Board of Trade should offer a series of local prizes for the best birds at the various fishing districts and villages of the United Kingdom, in which contests the local coastguards and naval reserve should be allowed also to compete.

Night and day, along the chief Norwegian fishing fiords and grounds, special local telegrams inform the fishing fleets as to the location, the probable destination, and expected time of arrival of observed shoals of fish. Doubtless much might be done on our own coasts by combining and collecting information for telegraphic purposes brought by these carrier pigeons as to the probable course of various migratory shoals of fish. Like the Chinese, the Norwegians, through centuries of acquired observation, are shrewd, trained experts in noticing the habits of fish. In 1888, while visiting the Norwegian fishing towns from Christiania to the North Cape and back, I was informed that the Norwegian Government gratuitously circulated these trade messages for the benefit and advantage of their fishermen. The Government of the United Kingdom should initiate similar plans on behalf of our neglected fishermen, as, setting aside the just claims of our brave fishermen for such trade information, this would also cheapen fish and thus relieve some of the burdens of tax-payers.*

Telegraphic communication between the light-houses and light-house ships and the shore is of inestimable value in case of many shipwrecks as well as for sea-fishery observations.

OVERFISHING BY MAN, BIRDS, AND FISH.

In 1376 Parliament was petitioned to stop, by immediate legislative interference, the increasing damage done by alleged excessive local sea-fishing by British fishermen. This agitation arose against the further employment of a new engine or instrument, "conceitedly and cunningly contrived," called a "wondy-choun," which was accused of destroying the spawn of fish and the spat of oysters and mussels. Introduced about 1369, the "wondy-choun" was probably an English invention of the original beam trawl or trail net for deep-sea fishing. The present successors of these fourteenth century grievance-mongers are well-meaning but ill-informed fish-trade quacks who publicly pose as the promulgators of the so-styled "immature fish questions." They ignore the elements of the natural history of marine fish life; they apparently sanction the eating of whitebait (a generic term for immature fish, chiefly herrings and sprats); they raise no objection to the use of lobster eggs (though almost tasteless) in sauces for fish; they permit the caviare or sturgeon-egg trade and the eating of the roes or eggs of herrings, cod, perch, pike, red mullet, etc.

Daily sea birds eat myriads of millions of fish eggs, of fish fry, of baby fish, and of sexually immature fish, besides multitudes of the fattest and finest mature table fish, often filled with ripe roes. At the mouths of salmon rivers sea gulls feast on salmon and sea trout of all ages, from the egg upward. In every twenty-four hours these winged anglers probably do more injury to the sea fisheries than all the united fish-catching engines and instruments of man in a whole century. Such evils are augmented and aggravated by these winged fish-poachers, feeding only upon the best food-fishes and eggs, leaving untouched predatory fish and their eggs, especially those of the dog-fish and shark. An excess of sea birds would first exhaust and exterminate marine food-fishes. These hungry birds would next eat up the predatory fishes and their eggs and other fishes considered at present too coarse for table or market. Taken in time, man could restore the "balance in nature" by destroying marine birds and their eggs. Sinking only when dying or dead, the living and fertilized eggs of most sea-water fish float about or near the surface. Hence deep-sea trawling can not injure such living floating eggs, but it does injure many aquatic plants at the sea's bottom, on which certain fish feed.

Marine food-fishes are preyed upon by birds and predatory fishes, including the ever hungry dogfish and shark tribes. Troops of dogfish will encircle and devour shoals of herrings, whiting, haddock, young cod, etc. To protect our marine food-fishes, the extermination of the dogfish and shark species is advisable. The bodies of dogfishes and sharks yield commercial fish-oils. Their skeletons are rich in phosphorous and lime, which, with their bodies, rich in nitrogen, worked up as fish flour, make excellent agricultural manure. Their dried skins can be manufactured into leather for special purposes, or else be used to polish wood and ivory. An excessive increase of predatory sea fishes might practically extinguish the marine food-fishes. Then the predatory sea fish would be forced to devour their own eggs and young. Especially when pushed for food, fish are cannibals.

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*A fisheries intelligence service, such as is here referred to, has been in operation in the various coast provinces of eastern Canada for several years. It is maintained by the Government at the remarkably low annual expenditure of $2,000. It has proved of much benefit to the boat and vessel fishermen of Canada, and would doubtless be of equally great value to all other countries having important coast fisheries.—HUGH M. SMITH.

DEVELOPMENT OF IRISH FISHERIES DEMANDED.

The coast and inland fisheries of Ireland should be properly developed by parliamentary grants and assistance. Ireland has a seacoast of 2,337 miles, and inland waters covering 574,887 acres, which supply chiefly a few salmon and eels. Nevertheless Ireland, for home consumption, actually largely *imports cured* fish. Where Irish railways exist, their stations are generally distant from the harbors; the result is, much fish is spoiled, and the cost of distribution of that which is saved is much enhanced. Besides refrigerator stores on shore, Ireland requires dry-air refrigerator steamers for its export fish trade, and refrigerator barges and insulated covered barges for its inland navigable waters.

Probably no better ground exists for the artificial propagation and rearing of lobsters for commercial purposes than the west and rocky coasts of Ireland. Oyster farming, such as is successfully carried on in Holland, France, and the United States of America, might also be attempted, by introducing young oysters into ponds and inclosed areas of water in salt-marshy districts bordering on the seacoast, where the transplanted oysters can be bred and reared for market purposes.

The pike, bleak, tench, and bastard carp thrive marvelously well, in number and size, in peat waters. This is a further source of wealth, industry, and food for Ireland, whose almost universal peat-moss litter makes excellent packing for dry-air-frozen fish.

The inland fisheries of Ireland at a trifling primary outlay should be made sources of national wealth and industry. Many of the Irish inland waters would answer admirably for breeding the sole, the female often supplying from 100,000 to 200,000 eggs at a time. The sole is justly considered the most digestible and palatable fish, and its flavor seems almost always acceptable. Unlike salmon, mackerel, whiting, eel, trout, cod, and other fish, including the herring, the palate even of the fastidious invalid does not get tired of the sole, which has also the merit of being cooked quickly and easily. I believe that, unless the sole is extensively artificially cultivated, within a comparatively short period it will become, as a food-fish, extinct. For reasons hitherto undiscovered, its already limited geographical area of natural production is gradually decreasing. In the battle of life and struggle for existence the sole will slowly but surely die out unless largely reared and farmed by man.

By gradual acclimatization sea fish can thrive and breed in fresh water if by degrees the proportions of saline matter be reduced to those of fresh water. Artificially cultivated in Irish inland fresh waters, soles, bled prior to the clotting of their blood, gutted, well-washed in fresh flowing water, and then immediately hard-frozen in dry cold air, could be profitably exported in colossal quantities to England, Europe, America, and elsewhere. Probably the American sturgeon would thrive in Irish inland waters. The American shad and alewife, both large herrings, which leave the sea to spawn in fresh water, should be experimentally introduced into Ireland.

35.—FOUL FISH AND FILTH FEVERS.

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DEFINITIONS.

(1) For practical purposes and for those of this paper "fish" includes aquatic and amphibian animals generally, as well as their products used or capable of being used for food.

(2) Except where specially stated or implied, I here use the term "fish" to represent food derived from dead aquatic and amphibian animals.

(3) Except where specially stated or implied, I here use the term "fisherfolk" to include fish catchers, curers. salters, preservers, and fish vendors generally.

BIBLICAL.

Accepting the accredited views of the ancient Egyptians, among whom as a quasi royal prince he spent his early life, Moses considered certain kinds of "fish" and other foods as the producers of "leprosy." The biblical leprosy evidently included almost every kind of skin disease and skin rashes generally. Hence Moses forbade the Jews to eat "fish" without fins and scales—oysters, shellfish, turtle, tortoise, etc.

Like the ancient Egyptians, Moses also believed that neither "fish"—aquatic and amphibian animals—nor insects and reptiles possessed any blood. Indeed these erroneous views seem to have not alone been indorsed by the rabbis who composed the Talmud, but even now by too many Jewish clergy at home and abroad, who are still alive.

Whilst Moses forbade the Jews eating hares, rabbits, pigs, and all creeping animals without wings, probably because these foods were then supposed to produce "leprosy" or other diseases in man, nevertheless he allowed his peculiar people to eat flying, creeping things, including such dirty insects as beetles, locusts, scorpions, grasshoppers, etc. Indeed the mere touching or carrying of the carcass of any animal considered unclean made the man and his clothes unclean until the evening, and until after he had thoroughly washed himself and his clothes. The Jews were also forbidden to eat the blood of beast or fowl. (See Leviticus, VII, XI, XIII, XIV.)

HISTORICAL.

The subject of fish inspection early engaged the attention of our forefathers. By a statute of Edward I, dated 1272, no fishmonger was allowed to water his fish more than once. No fresh fish was to be kept in London beyond the second day from its capture; nor was any bad fish to be sold.

In 1382 "Reynald atte Chambre brought in maliciously herrings and mackerel, corrupt and unwholesome for man," for which the mayor and alderman put him in the pillory for six days, and burnt his fish beneath him, as was then the custom of the city of London in like cases.

About the same time John Welburgham, who kept a fried-fish shop in Bread street, London, sold two pieces of cooked conger eel "rotten, stinking, and unwholesome for man," to four countrymen who went to dine at his house. They had the fish taken to Guildhall. There a jury of cooks, good men and true, were sworn to smell the fish, and by their verdict Welburgham was put into the pillory and his stock of fish burnt under him.

Compiled probably somewhere about 1419, or earlier, it was enacted by the Liber-Albus that "No fishmongers shall be so daring as falsely to *dub their baskets*, or to make a show of desirable fish at the top of the basket, and undesirable fish of little value beneath. On being attainted such a 'dubber' shall forfeit his fish to be burnt with fire in the Chepe—now Cheapside—in London. Such a dubber shall be held a cheat and imprisoned therefor."

In 1499, by 19 Henry VII, a trade search was made quarterly, or oftener as need should require, by the wardens of the Fishmongers' Company, who were to perambulate the whole city and suburbs for corrupt and unseasonable fish. The mayor for the time being was to punish and correct delinquents according to the laws and customs of the city. These laws were confirmed by the charter of James I in 1604 to the Fishmongers' Company.

Officially printed in 1620, "The laws and markets" of the city of London enacts that "no unwholesome or stale victual was to be sold; each offense to be punished by a penalty of 40 shillings and forfeiture of the victual.

The 1668 bylaws of the Fishmongers' Company—which the company professes to have religiously carried out from that date to this—in its trade duties include the prevention of the sale of "*overday*" fish, that is fish over a day or twenty-four hours old, by "*oasts*" hosts, innkeepers, or eating-house keepers within a radius of 12 miles of Billingsgate market. If the company were to enforce this law, the sale or distribution of bad fish in greater London and in its markets would be impossible.

It appears that on January 14, 1685, by 16 Charles II, the charters of the company were surrendered, but they were subsequently restored and confirmed.

FISH AND CHOLERA.

Unfortunately the present (September and October, 1893) outbreaks of cholera at Grimsby and at Hull (our largest fishing ports) further confirm the associationship of avoidable fishy filth and preventable diseases.

On September 4, 1893, at Bradford, a fish-hawker (John Walmsley) died, apparently from cholera. On September 2 he had obtained a consignment of mussels from the cholera-infected port of Grimsby (Cleethorpes).

At Rotherham, on September 6, Burnand died of cholera, having on September 5 visited Grimsby. He had been fishing the day previous to his death.

On September 8, at Doncaster, Hepworth, of Leeds, died of cholera, having recently eaten oysters from Cleethorpes in the port of Grimsby.

At Leicester, on September 10, a woman living at a fish and oyster shop died in a few hours, apparently of Asiatic cholera.

On September 14, at Mansfield, Notts, the wife of a fishmonger named Coleman died within twenty-four hours, of cholera.

In spite of the weather becoming suddenly much cooler, on September 22, 1893, at Newcastle, in its poor and crowded district of Byker, a fishhawker, Thurgate (or Stringate), died of Asiatic cholera, which he had previously fatally communicated to his friend and neighbor Platten.

The cockles and mussels in and about Grimsby and Cleethorpes are stated to be more or less sewage-fed, from the filth of the great fish-trade center.

Of all food trades the fishing populations are the most slovenly and dirty in their habits, overcrowded in their dwellings, and therefore more prone to endemic as well as epidemic affections; for, though apart from the manner in which inoculation occurs, cholera, jail fever, virulent smallpox, typhoid, typhus, diphtheria, leprosy, and the "plague," etc., have been always associated with poverty and avoidable filth, of course unwholesome food and dirty surroundings diminish our resistance to these infectious diseases, against which a healthier, stronger condition, obtainable by superior sanitary social surroundings and good food, becomes immune or free.

When light is thrown upon the present state of Grimsby and Hull, fishing ports of great importance, we find that their sanitation is very imperfect, that the fish trade has remained in its old-fashioned unhygienic ways, and that poverty has increased owing to the recent strikes. No wonder that these ports should form an apt *nidus* for disease. And, digressing for the moment, let me point out that in ports like Hull and Grimsby not only should we be exercised in preventing the entry of a *contagium vivum* from a foreign infected port, but by internal sanitation, dealing with our food-refuse, secreta, etc., we should prevent the origin of sporadic diseases.

Taking for granted that specific bacteria have been latent or dormant, "*sporadic*" *disease* suggests that local filth and other local causes are alone sufficient to produce and originate disease, apparently without any direct infection by infected persons or by infected imported clothing, rags, etc. Unless this view be accepted there appears to be no reasonable or rational explanation of sporadic disease, as of course in these Darwinian days of evolution no sensible person believes in "spontaneous" generation.

It is probable that the cholera bacteria may have been introduced last year or years ago into Grimsby or Hull, where the germs remained dormant till increasing filth and poverty, augmented by the recent local strikes, caused the cholera bacteria to infect some of the people at these seaports.

Whilst in strong, robust health, Pettenkoffer experimentally swallowed a lot of cholera bacteria, which practically caused him no inconvenience. Had he then been in ill-health this dose of cholera bacteria would probably have killed him.

No one can tell, therefore, that last year or years ago the inhabitants of these places and of other unsanitary fishing towns have not had mild attacks of cholera.

Tetanus, or "lock-jaw," essentially a dirt disease, is always with us, yet the tetanus microbe can only thrive in the absence of air, a circumstance which, one would think, would tend to have long since caused the extinction of tetanus.

Especially in the United Kingdom, practically all our leading fishing districts are more or less "health" resorts; thus, for all intents and purposes, Brighton is a railway suburb of London. It is therefore evident that the healthy condition of our seaports immediately concerns the inhabitants of our inland towns and districts.

In the 1893 cholera epidemic many visitors to Cleethorpes took cholera at this seaside health resort and carried the disease to various inland towns and places.

THE CHOLERA EPIDEMIC AT ST. PETERSBURG, FROM EATING BAD "FISH."

Doubtless, as the doctors declare, the long severe orthodox Russian church fast, which being in full force (December 16, 1893) and will remain so up to Christmas, 1893, has caused the poorer classes to eat bad "fish," producing intestinal disorders and increasing the winter abating cholera. It must be recollected that the exceptionally extreme mild winter weather has thawed the naturally frozen dead fish, making them dangerous food. The St. Petersburg, 1893, cholera epidemic had almost subsided till towards the middle of December, 1893, when a large number of soldiers and other people attended a colossal banquet at the winter palace on the occasion of the annual feast of the military order of St. George, which took place early in December, and subsequent to this several thousands of the guests who had eaten at the fête in the palace were attacked with cholera symptoms.

Early in January, 1894, at a St. Petersburg Orphan Institute, a rapidly spreading epidemic appeared, which within a week assailed 194 out of 200 inmates, or only spared 3 per cent of these residents. This attack was attributed to the consumption of fish contaminated with cholera bacilli from infected water.

Like the 1893 winter epidemic of cholera at Nietleben, in Saxony, and confirmed by Professor Uffelmann's laboratory experiments, these united facts show the resistance of cholera bacilli to cold.

THE PLAGUE IN ASTRAKHAN.

Astrakhan is the seat of the sturgeon and its caviare industries. The following remarks quoted from my papers in the "Practitioner" of 1880, show how foul fish may cause "filth" fevers.

During the winter of 1878 and 1879 the plague visited Astrakhan. Towards the latter half of November the real winter in Astrakhan begins, when its rivers are frozen over, whilst the temperature is often some 10° Réaumur below the freezing-point of water. In Astrakhan province most of the people seem well to do, but a fearful want of cleanliness is here as strikingly characteristic as in other parts of Russia. In the city of Astrakhan most of the streets are without pavement. There are no fresh-water springs, and the water supply is drawn from the fouled branches of the Volga.

The laborers employed in fish salting exist under very miserable conditions. In many places they dwell in cavities hollowed in the earth, or in caverns. The price of bread being beyond their means, they subsist chiefly on the leavings of the inferior parts of the prepared fish. Formerly Government rules enforced that the unused remains of the prepared fish should be thrown directly into the water, but now these, collected and accumulated in masses, are left to rot in and about the banks of the rivers under the heat of sometimes an almost tropical sun. Further, the vats used for salting fish are never properly and systematically cleaned. It is the custom merely to add more salt from time to time. The local atmosphere is further vitiated by many fat-boiling, fish-oils, blubber, isinglass, etc., works.

During the five years preceding the outbreak of plague in 1878, in Astrakhan, enteric fever, measles, and smallpox had been epidemic, whilst scarlet fever raged in

1876 and 1877. Previous to 1878 the town of Astrakhan during the last twenty-two years had suffered nine epidemic attacks of cholera and three of enteric fever.

Further statistics or observations of the twelve years ending 1878 recorded only one birth for every 36·5 persons, whilst one death took place for every 21 inhabitants of Astrakhan. Or, in other words, owing to preventable diseases due to avoidable filth, the population of Astrakhan would gradually become extinct were it not continually recruited and increased from external sources.

SUDDEN SPORADIC DISEASES ON SHIPS AT SEA.

On ships which have not touched land for months, when still at sea, if sporadic disease suddenly breaks out on board, this suggests overcrowding, dirt, putrefaction, infected drinking water, etc., with perhaps bad or scanty food *plus* privation, exhaustion, and the like, consequent upon continued foul weather, accidents at sea, etc. Below deck a ship is a floating house or hospital where the bacteria of disease may long remain dormant, till enabled to infect increasingly debilitated people.

Under favorable conditions and circumstances, where sufficient filth, heat, and moisture exist, there the latent, dormant, or passive germs of infectious disease are probably permanently present. These home-grown, indigenous, or endemic bacteria fortunately only occasionally assume the virulent and active pathogenic types, which produce epidemics.

In addition to the endemic form of contagion of course there is also the spread of infection by means of infected persons, clothing, etc. Passive or active germs, like plants, seeds, spores, etc., or animals and their eggs, etc., can also be imported and introduced as exotics or "foreigners" from abroad. Hence, in rare cases, there may be in the same place a series of contagious epidemics caused *conjointly*, *alternately*, *or successively* by the action of home-grown bacteria and by imported foreign bacteria.

FISH AND SPECIAL DISEASES.

Fish, filth, and poverty have also been suspected of producing such skin complaints as elephantiasis and ichthyosis (fish-skin disease), besides causing beri-beri, a tropical disease characterized by anæmia, paralysis, dropsies, dyspnœa, etc.

Decomposed animal or vegetable matter tends to propagate and circulate fever and disease. Fish putrefies quicker than meat, game, poultry, fruit or vegetables. Indeed fishermen themselves are so acutely alive to the early rapid putrefaction of fish that an ancient and still familiar name for a kind of rock or whiting pouter is the "stink-alive."

Of all our food industries, none is so constantly and belligerently offensive as the proverbial fish and fish-offal trades, as a visit to bacterial Billingsgate and its abominable colossal underground vaults will prove.

HEREDITARY SUSCEPTIBILITIES TO "FILTH" DISEASES.

Recent history confirms that disease and death from "filth" fevers may be increased by hereditary tendencies. H. R. H. the late prince consort, Prince Albert, is reported to have died from typhoid fever, probably produced by the filthy emanations from a dust bin, accidentally placed near his bedroom window. His son, H. R. H. the Prince of Wales, very nearly died of typhoid fever, caught whilst on a visit to a nobleman where the drainage and sanitation were defective. His grandson, H. R. H. the Duke of Clarence, is reported to have died from eating oysters which had been contaminated by having lived in sewage-fed waters.

WOUNDS CAUSED BY HANDLING FISH.

These are often serious owing chiefly to an accidental dose of putrefactive matter getting into the sore, producing local whitlow or cellulitis, abscess, necrosis, loss of finger, or even fatal gangrene. The average fisherman has never any remedies at hand at sea, unless it be a quid of tobacco to put on the wound.

Surgeons attached to the Mission to the Deep Sea Fishermen have noticed that, in spite of the usual health of these fishermen, wounds heal but slowly at sea. Whilst cleaning fish slight abrasions, punctures, and cuts from knives soon inflame, causing deep suppuration and great suffering. The poisoned wounds of such fisherman are generally irritated by salt water, which soaks through their bandages.

Their putrefactive surroundings from decaying "fish" seem to suggest that the putrefactive bacteria and products connected with the decomposition of "fish" may account for the slowness with which fishermen recover from sea boils, salt-water cracks, and local injuries from the skin having been cut or torn.

These injuries resemble the course of "wound fevers" in armies during war, etc.

I have quoted these instances to suggest a more intimate relationship between the effects of the prick or wound and the resulting inflammation than has hitherto been supposed, and that these cases may point to a direct inoculation of putrefactive virus contained in foul "fishy" surroundings.

During October, 1892, at a coroner's inquest upon a fish porter, it was shown by Dr. Rolf, of the London Hospital, that death was due to the rapid cellulitis and gangrene which followed from the prick of a fish bone.

In the British Medical Journal of July 6, 1889, I called attention to the case of a woman, described by Dr. Buckell, where the patient pricked her tongue with a fish bone, and then was said to have inoculated the wound with vaccine virus, owing to her having kissed her baby's vaccine vesicle. Now, in this case the inflammation of the tongue might just as well have been due to the poison of the wound by the fish bone.

Again, rectal abscess in man is often due to a fish bone penetrating the local mucous membrane. Goodsall describes eighteen cases, and there are numerous others mentioned by writers at home and abroad.

In these examples, in like manner, inflammation may be due to wound-poisoning caused by the bone, and not to the mere mechanical irritation excited by the foreign body, and the necessary contamination of the wound with the local excreta.

In some parts of the United States their oyster "fishermen" or dredgers, owing to being wounded by the shell of the oyster and the putrefactive poison derived from the decomposed "fish," get on their hands one or more large abscesses, usually situated beneath their nail or nails. This affection is described as a huge "felon," or a kind of general paronychia or whitlow of the hands. The bones and tendons are often exposed, with possible loss of one or more fingers. The usual American treatment is deep and free lancing and improvement of the general health and surroundings of the patient.

Old hands having long manufactured dry mother-of-pearl, tortoise-shell, horn, ivory, bone, etc., are liable to impeded breathing, shortness of breath, or cough, probably caused by breathing in the dry dust made in their business. In other instances the organic dust made by workers of mother-of-pearl, being absorbed into their lungs and thence into their blood, causes an affection at the end of their bones near the joints, simulating the symptoms of acute rheumatism. Sometimes mother-of-pearl workers have had various bones, especially those of the lower jaw, wrists, collar-bone, etc., attacked with severe *periostitis*, or inflammation of the bone's external lining membrane. It is supposed that the mother-of-pearl dust contains traces of phosphorus in the form of phosphate of lime.

In the United States "gurry" (or fish-offal) sores on the hands, wrists, and arms of its fishermen are common. These wounds are caused by the poisons, chiefly putrefactive, derived from fish-hooks, fish-pins, fish-scales, and from handling fish. These "gurry" sores are made worse by exposure to wet, extreme cold, or excessive heat, and often aggravated by dirt and poverty.

"PROFESSIONAL" PUTREFACTIVE POISONING.

In the Norwegian whale fisheries, after having driven the whales toward the shore, they are surrounded by a net, which prevents them through fear returning to the deeper sea. The whales are next struck with prepared putrefactive-poisoned harpoons. In about twenty-four hours some of the whales begin to exhibit sign of exhaustion, probably through septic or suppurative poisoning, and are hence readily captured. It is then found that the harpoons are imbedded in masses of inflammatory gangrenous tissue. These harpoons are removed and carefully preserved without being wiped or cleaned, to be employed for the next shoal of whales, when they are again used, producing and repeating their septic or poisonous properties.

The explanation of this rapid poisoning is due to the harpoons carrying with them the germs or bacteria of an infective inflammation and inoculating the whales by setting up infective or poisonous inflammation in the same way as spreading gangrene, fatal erysipelas, and child-bed fever.

Nero and Domitian used special putrid preparations made from the sea hare (*Aplysia punctata*), a kind of sea slug or snail, for secretly poisoning their enemies. Similarly, some savages use dried putrid fish poisons for their arrows to kill men and animals.

PUTREFACTION.

To satisfactorily study and intelligently understand the putrefactive processes of animal matter it is sometimes necessary to compare the decomposition of meat, of game, of poultry, and of fish, and even also the decompositions which occur in living and in dead vegetable matters, including flowers. Hence I have considered it occasionally advisable to enter into the *comparative chemistry and comparative bio-chemistry* of putrefactive processes which occur both in living and in dead men, animals and plants, without forgetting certain other facts bearing upon the question of natural food preservation.

As an illustration of the power of putrefaction, even in quantities which probably could not be weighed on even the most delicately contrived balance in the analytical chemist's laboratory, let us recollect what may take place in the "putrid" sting of a filth-feeding wasp. Thus, during the summer of 1893, in various parts of the United Kingdom there were several serious cases of poisoning, and sometimes fatal poisoning, by stings of these apparently insignificant insects. Occasionally these stings produced a bright-red mottled rash, just like the rash which follows upon eating bad "fish," especially shellfish, above all periwinkles and mussels, more or less "on the go" or tainted, which bring many cases of suspected poisoning to the local medical man, who generally cures his patients with a prompt emetic and purge.

While bees are vegetarians, wasps are filth-feeders, greedily devouring dirt and decomposed animal matter. Hence it is probable that fatal cases resulting from wasp stings are caused, not by the acrid and the specific secretions of the wasp, but are due to the infuriated insect inoculating accidentally a very minute dose of putrid poison.

In Exodus XXIII, 27, 28, Deuteronomy VII, 20, and Joshua XXIV, 12, we read of hornets being sent to drive out and destroy enemies.

From time immemorial in Eastern countries the sting of the wasp or hornet was considered as venomous and deadly as oriental leprosy.

The Talmud declares that the lion fears the mosquito, the elephant the gnat, and the scorpion the ichneumon fly.

Without suffering from their stings, wasps are devoured by toads.

The importance of the question of putrid food will be readily appreciated when it is recollected that quite recently a well-known London modern medical writer has boldly stated that "though you may eat and drink cholera, you can not possibly catch it." Personally I believe that cholera is infectious, but that bad food and water may also communicate the disease.

In 1848 Prof. Virchow showed that the symptoms and anatomical changes caused by injecting putrefying fluids into the blood of animals most closely resembled cholera.

Ancient physicians wisely assumed that there were both a *status putridus* and a *febris putridus* in foul fevers, and that all these infectious diseases contained a common putrid element.

DOMESTIC ANIMALS POISONED BY BAD FISH.

Especially at the seaside, or near fish shops and fish markets, dogs are particularly liable to putrefactive poisoning and choleraic conditions, more frequently originating by their having eaten bad fish than from any other kinds of decomposed animal or vegetable matter. Because of their so readily vomiting unhealthy food, though proverbially fond of fish, cats suffer much less than dogs. From time immemorial, in some oriental countries, at certain seasons, when fish is suspected to be specially poisonous, the natives feed suitable domestic animals on the fish, when, if no bad symptoms occur in the animals experimented upon, the people eat the fish.

In man, but for the fact that "fresh and cured" fish (*i. e.*, aquatic and amphibian animals and their products used as food) produce in many cases immediate vomiting and diarrhœa, fish-poisoning would be practically universal. There are numerous diseases directly attributable to eating bad fish or neglecting to destroy its offal. I may mention, for instance, that domestic animals act as hosts to parasites, which attack some races of Northern Europe and Asia. The eggs of the parasites are propagated; these may dry and get distributed; or else dogs eat them and then pass them, thereby often contaminating local drinking-water supplies, etc. Tape-worms, and various other worms infecting man, hydatids, etc., are thus frequently introduced, especially when men and animals drink out of the same vessels.

TREATMENT OF BITES AND WOUNDS CAUSED BY HANDLING LIVING OR DEAD FISH, ETC.

(1) Ammonia, as sal-volatile, smelling-salts, etc., or other available alkali should be immediately placed on the bite, sting, or wound.

(2) Subsequently a little Condy's fluid (permanganate of potash) should be poured on the wound, so that in case of the animal inoculating any putrid matter into the patient, such poisonous material shall be at once disinfected and destroyed.

(3) The immediate pain and itching from bites of animals seem due to something more than the mere acidity of a secretion. The pain and itching depend, probably, rather upon the introduction of some specific irritant, possibly distinct and peculiar to almost every large class of insect and other animal.

(4) Where practicable, especially owing to possible putrefactive properties, the sting, etc., should be extracted as soon as possible.

(5) The same method of treatment is equally applicable to bites from domestic animals, the stings of serpents, and to various injuries caused by amphibian and aquatic animals, to which fishermen and sportsmen are liable.

FOULED FISH AND FISHY FILTH.

Offensive fish markets and fish shops, stationary or perambulating costermongers, evidently come under the section of offensive trades, exposing the delinquent to a first penalty of a sum not exceeding £2, and subsequent convictions may, even for a single offense, amount to £200.

The public health ships act (48 and 49 Victoria, 1885) confirms section 110 of the 1875 public health act, extending the powers so as to bring ships within the jurisdiction of the local authority in which the ship is lying. This would evidently include all fish-carrying vessels under the jurisdiction of the public-health acts of England.

By the 1890 public-health amendment act and the 1891 London public-health act any solid or liquid article or animal intended for the food of man, exposed for sale or deposited in any place for the purpose of sale, or in preparation for sale, may be seized and, if found diseased, unsound, unwholesome, or unfit for the food of man, the medical officer of health, the inspector of nuisances, or their representatives, may seize, condemn, and destroy the said article or animal. For every such improper article exposed or prepared for sale, etc., the would-be vender or food-preparer seems liable to a fine of £50, or else a term of imprisonment not exceeding six months with or without hard labor.

Fishing ports or districts and fish shops, stores, and markets are proverbial for their now avoidable abominable smells and worse sanitary arrangements.

Though from their earliest history the Norwegians, immediately on capture, have always bled their fish by incisions just under and behind the gills, yet British fishermen have never generally adopted this practice, which, combined with gutting on capture and improved methods of curing, secured to the Dutch the practical monopoly of the fish trade of the world, between the fourteenth and eighteenth centuries.

In the United Kingdom its fish venders consider it necessary to sell their fish looking full, fat, and round within, and wet without. Hence till the fish is bought it is usually unbled and ungutted, whilst to make its skin and surface look bright and wet, it is kept artificially soaked and sodden with water or melting ice, or both. What butcher would so ill-treat his meat?

Only after the fish is sold, the trade then gut the fish, which is already too stale to bleed, as the blood is mostly clotted and usually more or less decomposed. Their so-called cleaning, if any, consists in placing the "fish" in a small tub or pail containing a super-saturated solution of fishy filth and offal, reeking with almost every obtainable form of putrid bacteria, and the putrid products of parasitic worms and their eggs, etc. Fish costermongers or itinerant fish-venders, frequently carry on this offensive trade at the very doors of their customers, a practice which ought to be illegal and punishable.

Meat, etc., can not be successfully dressed near a foul gully, cesspool, drain, dunghill, dust-bin or other receptacle containing putrefactive bacteria and their products.

Fish decomposes with extraordinary rapidity, partly because its shorter, lighter, looser muscular fibers both contain more and absorb additional moisture more readily and abundantly than is the case in the denser, longer, stronger muscular fibers found in meat, game, poultry, etc.

FISHY ODORS.

An ancient Tuscan proverb accuses fish and guests of stinking from the third day.

The filthy but frequent habit of our costermongers and itinerant fishmongers of "dumping" or depositing their fish offal and fish refuse on the road is pregnant with danger, especially during warm wet weather. In 1890 I published the fact that around bacterial Billingsgate, if a street stone be removed a horrid overpowering stench arises from the local foul festering fishy filth having supersaturated the soil.

A Billingsgate fish salesman once said:

> The smell of fish in a market would permeate every part and room of the neighborhood for a quarter of a mile round. You can have no idea of the tentativeness of the smell, and the people would be poisoned. A short time ago I went to the theater and sat behind several ladies. In about half an hour I heard, "Dear me! What a strong smell of sprats!"

It is evident that in the theater this man must have carried about with him the putrefactive bacteria of foul fish, which proved so offensive to the ladies in front of him. In other words, as soon as the heat and closeness of the theater made him warm and perspiring, then the fishy bacteria and their products gave out their putrefactive characteristic odor.

Shakespeare was familiar with the "very ancient and fish-like smell" of such putrefying matter.

In 1888 whilst traveling from the North Cape, in northern Norway, we visited for less than half an hour a local whale factory. On returning to our steamer, which was continually moving quickly southwards, nevertheless for about five days the offensive smells of the decomposing whale stuck to our boots, clothes, hands, etc.

Passing nausea, sometimes accompanied by vomiting may be caused by merely smelling putrid fish and "fish" offal.

The public-health (London) act 1891, by section 21, paragraph 1, provides that "Where any trade, etc., causing effluvia is certified to be a nuisance, etc., (1) by the local medical officer of health, or (2) by any two legally qualified medical practitioners, or (3) by any ten inhabitants of the district, and the complaint laid before the local sanitary authority, then such authority shall make a complaint to the local petty sessional court, which, unless it is shown that such person or trader has used the best practical means to abate the nuisance, etc., prevent or counteract the effluvia, the person or his representative so offending is liable to a fine not exceeding £50.

Consult sections 35, 47, etc., of this 1891 act, and also the public-health acts amendments act, 1890, sections 25-31 inclusive. Of course these acts apply to fish shops or stores, public fish market, etc.

The public health (London) act 1891, by sections 134 and 135, state that where complaint is made to the local government board, that "the commissioners of sewers have made default in executing and enforcing any provisions of this said act," that then the local government board has the legal power to compel the said commissioners of sewers—*i. e.*, the corporation of the city of London—to carry out the sanitary and other provisions of the public health (London) act, 1891.

If we can not expect, then at least let us hope, that public opinion as well as the financial interests of the fisherfolk, fish-venders, and the local municipal authorities responsible for the cleanliness of our public food-markets will themselves speedily put and keep their own trading-places in good order and healthy conditions. If not, there is ample legal power under the various acts which I have already quoted, especially under provisions contained in the 1890 and the 1891 public-health acts, to enforce the necessary remedies. By future legislation these remedies should be made strictly *compulsory* upon the local sanitary authorities and no longer left to the optional action of more or less private individuals.

LOCAL MEDICAL OFFICERS OF HEALTH TO BE APPOINTED FOR LIFE.

The weak and breaking point of the sanitary administration of the United Kingdom is the unfair, unfortunate, and uncertain position of the local medical officer of health, who is too often practically dependent and depending upon the mere majority of the unpaid members of the local municipal body.

The municipal body, though personally "well meaning," may be more or less ignorant, incompetent, prejudiced, or impractical faddists—or worse still, one or more of its members may be directly or indirectly interested in defiance of public law and public good, in upholding the very abuses and nuisances which the medical officer of health desires to extinguish. If, however, the whim of a bare majority of a municipal body can deprive its medical officer of his position and livelihood or make his official existence a continued misery and martyrdom, how can such a specialist and scientist carry out the official and moral duties of his station as public local trustee of the health of his community?

After election and appointment by the local municipal body, the medical officer of health should only be removable after being legally proved unfit at a bona-fide public inquiry, say, presided over by the local government board or other competent tribunal. Like judges, magistrates, coroners, etc., the tenure of office by the local medical officer of health should be for life, or else up to a certain age, with a pension to retire upon.

The public health (London) act. 1891, by its sections 82, 83, 110, and 113, demands that the local sanitary authority shall provide all such acts, matters, and things as may be necessary for mitigating any disease, these powers extending to trading vessels lying in their local ports, rivers, waters, etc. The removal or prohibition of avoidable filth is, of course, included.

STRIKES, POVERTY, FILTH, AND DISEASE.

By lowering the local general health and means to obtain sufficient suitable food and healthy lodgings, added to excessively exhausting excitement, increasing privation and augmenting poverty, caused by the recent protracted colossal Hull strike, may have indirectly contributed to the subsequent appearance of the cholera at the Humber ports. During the strike the sanitary state of the city, especially in its poorer quarters, would necessarily have been more or less neglected. This means that poverty favors the tendency to and opportunity for local filth accumulations.

The present frequent colossal British strikes are practically localized civil wars. Apart from the irreparable injuries which they inflict upon the capitalist, trade, strikers, and their dependents, these strikes also tend to start local, if not general, disease throughout the Kingdom. (In the Times of April 9, 1878, I showed the horrible diseases which follow war.)

It appears that when these strikers and their families are practically starving or semi-starving, the local authorities decline to give them relief, even though the trade unions on which these poor people depend are apparently bankrupt, and when the sources of private charity are also dried up. Though probably no nation would now dream of going to war unless it had arranged a satisfactory food supply under a commissariat, nevertheless strikers too often commence their civil war without funds and food.

Foul fish fostering filth fevers (which are alike avoidable by superior sanitation) is a lesson yet to be admitted, acknowledged, and appreciated by the general public, who probably has now to thank the hitherto impenetrable ignorance of its fisherfolk and fish-venders for the present (1893) invasion of cholera in the United Kingdom.

Apparently the 1893 cholera epidemic was *home-grown* or *home-made*, and chiefly caused by deficient sanitation, due to avoidable local filth accumulations of animal matter in which decomposed fish and fish offal have been the principal factors. In these circumstances there is no reason to suppose that the 1893 cholera epidemic was imported from abroad.

Instead of being disinfected by carbolic acid and other falsely reputed specifics for destroying putrid material, all bad fish and fish offal should be ***burnt up*** in suitably constructed *furnaces*. I shall again refer in detail to the importance of this subject, which hitherto has unfortunately been generally neglected by home and foreign sanitary authorities. Suffice it here to say, that usually in our fish centers and markets decomposed fish is stacked and sprinkled with a small quantity of disinfectant, often carbolic acid, absolutely insufficient to cancel all the injurious effects, yet quite sufficient to destroy it for manure or other agricultural purposes.

FOUL FISHING BOATS AND FISH BOXES.

In the United Kingdom the too usual plan is, so long as the vessel keeps at sea, that all its catch is kept together for sale. This fish is unbled, ungutted, and uncleaned. It is frequently bruised and damaged, and stacked in such large masses that the lower strata of fish suffer incredible injury. Arriving at the fish pier, beach, or station, it is again bruised and banged about in foul, filthy boxes, pregnant with every kind of putrefactive bacteria and their products. To make matters worse, it is usually packed in ice and melting ice, which rapidly rots and ruins fish, that, of all animal substances, most requires to be kept perfectly *dry*. As fishing vessels, as well as fishing ports, piers, beaches, and other districts where fish is landed, are fully as offensive as most private slaughter-houses, it is only fair that on landing all such fish should be inspected previous to being sold or offered for sale as food in their special localities of arrival or else forwarded for sale as food to distant markets.

There appears to be considerable confusion as to the duties of the port sanitary authorities as to their on the spot seizing, condemning, and destroying fish unfit for the food of man. It is evident that no bad fish should be allowed to be sold locally, or offered for sale for the purpose of food, or forwarded by rail, etc.

As the delivering of bad fish on land is an offensive nuisance, dangerous to public health, all bad fish on landing, after inspection, should be destroyed in suitably constructed furnaces.

Abundant evidence that fish is already rotting when dispatched from the fishing ports is to be found in the corporation fish and Billingsgate inquiries of 1868 to 1870 and in the 1881 reports, as well as in the evidence before the House of Commons in 1882 on the Shadwell fish-market inquiry.

George Stevenson, a fish salesman and auctioneer and a member of the corporation markets committee, recorded the following evidence:

> I have been in Billingsgate Market for sixty years, where I did the most mighty business in London. The corporation absolutely made the basement of Billingsgate 25 to 30 feet below the waterway. We spent something like £50,000 to £70,000 to clean out cart loads of human excrement from that basement. Billingsgate is an abortion above and a cesspool below. At Billingsgate the diseased fish is sold very cheap, where the *filth* fetches a very low price.

Other witnesses swore that the railway fish muck came in a half-stinking state to Billingsgate.

Another smack-owner declared that he loaded his fish in railway bullock trucks with the muck or manure not cleaned out.

Another witness swore that the railway fish barrels, when delivered from the trucks, were so filthy from adhering manure that he had to wash the fish before taking them on his back.

Again, another swore that the great bulk of fish condemned in Billingsgate ought never to have got there. Fish meters or inspectors of the Fishmongers' Company have also stated that the fish was bad before it started from the railway station at the fishing port.

Another fishmonger stated that he had sold stinking fish.

Further, another of the fish meters or inspectors of the Fishmongers' Company, with whom he had been for ten years, stated:

> After we (the Fishmongers' Company) have condemned the fish, even if it stinks so badly that you can hardly go near it, nevertheless we have plenty of poor people who take away whole baskets full. They wash it, clean it, and eat it. I know this as a fact from my own personal experience.

A Billingsgate fish salesman said:

> I know for a fact that the refuse of the fish all comes to Billingsgate. Hull and Grimsby furnish much inferior quality of fish. Hence on the coast I have heard the remark "anything will do for London."

A fish meter stated:

> The jurisdiction of the Fishmongers' Company extends 12 miles round, but the farthest place I have ever been to is about a mile and a half from Billingsgate.

There are three distinct methods of effectually disinfecting empty porous, rough, sodden, supersaturated, saline, stinking, foul fish boxes, trunks, baskets, etc. In the fish trade these receptacles are technically termed "*empties*."

(1) *Prolonged boiling* during several successive hours, which is quite impracticable in the circumstances under consideration.

(2) The action of *superheated steam* at about 300° F., or more.

(3) *Baking or prolonged exposure* during several successive hours to dry heat of about 300° F., which would be impracticable because of the resulting shrinking of the wood.

It must be recollected that porous, uneven, sodden supersaturated fish trunks, boxes, and baskets, pregnant with putrefactive bacteria and their products, are especially difficult to free from moisture, owing to the hygroscopic or water-absorbing qualities of the sea-salts, with which these receptacles are impregnated. This is another reason why sterilization by superheated steam would, by dissolving out the sea-salts, be a more effectual procedure than the application of dry heat, which would fail to extract the hygroscopic sea-salts. In other words, dry-heating or baking would lead to the concentration of the sea-salts in the wood.

If my long-advocated plans for making fish "*imperishable*" by bleeding before blood clotting, immediate gutting, thorough cleaning with abundant flowing (sea) water, and dry air refrigeration, were adopted, then the expense and inconvenience of these bulky fish-trade boxes, etc., would be no more required than in the meat trade, nor would the purchasing of ice and melting ice be necessary.

SANITARY FRESH-FOOD MARKETS.

Unfortunately most of the fish markets in the United Kingdom are as unsuited for receiving fish as a befouled sewer would be for a larder. The internal building materials, including their walls, pavements, and ceilings, suggest that accident and intention had conspired together to construct colossal sponges, or bacterial traps, adapted to suck up, in the shortest time, the maximum amount of putrid and putrefying filth. Most of these markets exhibit collections of fish offal and fish refuse on their premises, and are frequently as offensive as ill-kept slaughter-houses. It is important that the premises used for fresh-food storing should be made of glazed, level-faced, non-absorbent materials. The roofs of such markets should be only of glass and metal. The flooring or pavement must be even, non-porous, non-absorbent, hard, but not too slippery. For cleansing and disinfecting purposes, the flooring of public markets requires a good gradient or fall towards the gutters and outlets. To exclude the germs of putrefaction and contagion, cleanliness, dryness, and low temperature are essential.

Where possible every fish market should have on its premises a suitably constructed furnace, to at once destroy bad fish and fish offal, which above all should not be allowed to be carted through a crowded city with narrow streets.

In ordinary gas burners, where the combustion is not very perfect, for each cubic foot of ordinary coal gas burnt, nearly three-fourths ounce of water is produced, furthering the early spoiling of fresh animal foods. In a closed room, the excessive burning of gas may saturate or supersaturate the contained air, as is frequently observed on glass window panes, and the dripping moisture staining and spoiling absorbent and porous wall papers, etc. Besides heat and moisture, the burning of gas evolves some carbonic and sulphuric acids. Generally, in fairly well-made coal gas, ammonia is absent, but, if present, it occurs only as a slight trace, when it burns off as nitrogen and water. For London the legal maximum is 22 grains of sulphur in winter and 17 grains in summer per 100 cubic feet of coal gas consumed, but the average amount in the metropolis is only 12 grains per 100 cubic feet of coal gas burnt.

Except perhaps the Siemens hot-blast burners, probably no gas-burner consumes the whole of the coal gas, but always lets some of the gas escape unburnt into the atmosphere. Therefore every room lighted by gas contains, besides carbonic acid, water-vapor, and sulphuric acid derived from the gas, also some carbureted hydrogen and carbonic oxide. Coal gas contains up to 20 per cent of carbonic oxide. Thus Erdmann found in the air of a room which had been lighted by gas 0.056 per thousand volumes of carbureted hydrogen (marsh gas). At the same time he discovered that candles burn as a rule still more imperfectly than gas; as much as 0.187 per 1,000 volumes of marsh gas resulting in such a case. He also found that candles produce fatty acids and acroleine in the air.

The following figures by Erdmann may be interesting in this connection. With electric arc light no water-vapor was evolved, and only traces of carbonic acid, and only from 57 to 158 calories of heat. With the Siemens hot-blast burners no carbonic acid or water came into the room. With Argand burners 0.86 kilo water and 0.46 carbonic acid, with evolution of 4,860 calories. (Siemens burner, 1,500 calories.) With a two-hole burner, 2.14 kilo water and 1.14 kilo carbonic acid, heat 12,150 calories.

In all gas combustion also some nitrous acid is formed which is very irritating and prejudicial.

With an incandescent electric-light burner, nothing ought to come into the room and the heat produced is small.

The worst illuminants as to water and carbonic acid are candles and fluid oils.

Slaughter-houses, meat stores and shops, fish shops, and fresh-food markets are best illuminated by incandescent electric light, which yields no combustion products. (In the electric arc lights, their carbons burn bodily away, producing carbonic acid.)

In crowded market-places additional impurities and moisture are given off by the processes of respiration and perspiration, which further contaminate and vitiate a limited supply of repeatedly overbreathed air, especially damp, warm, still air as occurring during fogs, mist, rain, etc.

During sunlight and activity it appears that an average adult will, through his perspiration and respiration, give off roughly about, more or less, 3 ounces of water per hour, besides considerable organic impurities and some carbonic acid. (During sleep these exhalations are considerably diminished.)

In densely frequented markets much dirt is unavoidably brought in from the streets, stables, etc., sticking to the boots of the visitors. This wet mud and filth necessarily adhere to the too porous, uneven, damp, dirty pavements of many of our market-places.

As to the impurities produced by respiration, besides carbonic acid and water, there are always formed ammonia, volatile organic fatty acids, sulphureted hydrogen.

Seegen and Nowack have also alleged that respired air always contains organic hydrocarbons, but this is doubtful, and any that may be found comes more likely from the intestines.

INFECTION OF FISH BY IMPURE PRESERVATIVES.

Fish must be kept perfectly dry, and of course melting ice or other added moisture scrupulously avoided.

When ice or melting ice is used for preserving food, as in the fish trade, or for drinking purposes, it should be made only from *distilled water*, where the receivers are kept perfectly clean and the water or ice properly stored.

The temperature at which artificial ice is made is probably much lower than that in the case of natural ice; therefore in artificial ice the chances of killing by cold traces of living organisms (bacteria, etc.) would be greater than in natural ice, especially that from small, shallow, dirty ponds at the freezing-point of water. Hence the Paris police prefecture has recently (1893) forbidden the use of ice taken from certain lakes and ponds in and about Paris, as it was found that such ice contained large quantities of unhealthy organic materials and bacteria, rendering its use for table purposes dangerous.

In the United States several outbreaks of typhoid fever have been traced to the use of infected ice taken from natural sources.

As it seems almost impossible to satisfactorily test the purity of natural ice and its freedom from organic tainted matter, one is driven to protest against the use of natural ice. As our present law stands, any filthy water frozen into ice may be sold for food and drinking purposes. In England there seems to be no supervision over the ice used for food, and it does not appear to be provided for by any of our acts of Parliament. I am not aware that there have been any legal prosecutions in reference to the sale of infected ice in the United Kingdom. It is a curious superstition and a common error which induces most people to imagine that ice made from dirty water is pure.

St. Luke said: "Salt is good; but if the salt have lost his savor, wherewith shall it be seasoned? It is neither fit for the land, nor yet for the dunghill; but men cast it out. He that has ears to hear, let him hear."

In fish-curing so old was the grievance against the use of dirty and impure salt by the fish-curers that already, by 12th Anne, cap. 2 (1713), it was enacted that all foul salt should be thrown overboard and destroyed to prevent its employment in curing fish.

From 1866 to 1884 French soldiers and sailors in Algiers suffered from poisoning after eating red-salted cod, due to bacteria, attributed to the foul salt derived from marshes near Copenhagen. At other times to minute low-typed water or algous plants frequenting shallow seashores, and often included in the crystallized sea-salt made by solar evaporation. The bacteria appear to have been the *Clathrocystis rosea persicana* of Cohn, *Sarcina morrhuæ*, or *Sarcina littoralis*, according to different observers.

In 1878, after eating red-salted codfish, a fatal case occurred at St. Petersburg. Some consider red-salted codfish harmless unless associated with the putrefaction of the fish. Salted sturgeon has also proved fatal in Russia. A circular dated December 31, 1885, by the French minister of commerce, forbade the sale of red-salted codfish, exposing the vendors to the penalties of imprisonment, seizure of their goods, the publication of the judgment by means of placards, and making the dealers responsible for sickness arising from eating red-salted cod.

In spite of these facts, some chemists, apparently in error, have doubted that salt can ever become red from bacteria, or fungi, any more than the usual redness of carbolic acid can be attributed to such causes.

Insufficiently or soft-salted codfish absorbs from the atmosphere more moisture in their flesh than well-salted codfish, and consequently weighs heavier, yielding more profit to the unscrupulous fish-vendor. Such red-salted cod is accused of infecting curing-houses, fishing vessels, warehouses, and wharves.

Salt is sometimes red from containing the red hydrated oxide of iron, which has nothing to do with this red-salted codfish. This red-salted codfish must not, of course, be confused with the so-called red codfish, especially good eating, whose color is attributed to its excessive feeding on shellfish and starfish, nor yet for codfish slices ingeniously dyed red and sold by a fraudulent trader.

Norwegian "sardines" are sometimes red, as alleged from inferior salt. A foreign Government has recently offered a premium in money for the best means to prevent salt from absorbing moisture.

BACTERIAL INFECTION OF FISH, MEAT, ETC.

Cooked and salted meats, as ham, beef, mutton, veal, pork, etc., frequently show iridescence, similar to that produced by light falling upon the scales of freshly-caught fish. This iridescence usually affects only a part of a cooked or salted joint; but it may possibly be associated with decomposition in another portion of the same joint. This iridescence seems due to conditions probably preceding decomposition, rather than necessarily accompanying putrefaction. Where the meat has been otherwise sound, sweet, and healthy, often have I eaten, and seen others eat, iridescent cooked and salted meats without my having been able to trace any subsequent disturbance or illness therefrom.

However, I consider iridescent meat as suspiciously doubtful, and especially inadvisable where any lesions may exist along any portion of the alimentary tract, and above all to be avoided where there may be ulcerations about the intestines. Whilst myself further investigating this matter, I shall be grateful to learn of any clinical, pathological, or bacterial work or research on this branch of meat inspection—a subject which has received too scanty attention from medical men. Though I have never yet noticed any iridescence on cooked fish, there appears to be no reason why it might not occur. Some writers and observers have actually mistaken phosphorescence for iridescence.

Bacillus phosphorescens produces phosphorescence in herrings and other aquatic animals. This bacillus or germ, when artificially grown in very large quantities on nutrient media, may in the dark emit sufficient light to enable one to see the time on a watch, etc.

In November, 1893, Prof. Klein showed that red or pink patches which had been observed on cooked meat and cooked fish were due to the *Bacillus prodigiosus* (a non-sporing bacillus), killed in a few seconds by a temperature of from 70° to 75° C.

In investigating the matter Dr. Klein came to the conclusion that the bacillus was due to the fact that a neighboring churchyard (which had been unused for generations) had been recently dug up, its human remains removed, and the old walls pulled down. During this process a strong southwesterly wind chanced probably to blow the disturbed microbes into the larder where these foods were kept.

In other words, the pink patches of the *Bacillus prodigiosus* observed on cooked meats, etc., seem due to conditions favored by moisture probably preceding decomposition rather than necessarily accompanying active putrefaction.

The hygroscopic action of common salt, especially if accidentally adulterated with chloride of magnesium, as in salted and cooked meats, suggests that moisture favors both the development of the "pink" patches of bacteria and the reddening of foul salt.

Those who had partaken of the "pink" meat and "pink" fish or salted meat did not suffer from any subsequent disturbance or illness. Nevertheless I believe that "pink" cooked food stuffs caused by the invasion of the *Bacillus prodigiosus* should be avoided where there are any lesions in any portion of the alimentary canal, and especially where there are ulcerations about the intestines.

The *Bacillus prodigiosus* has been long been known to spontaneously infect food. It probably caused the so-called "bleeding bread" and "bleeding host" so superstitiously dreaded during mediæval history. When this bacillus occurred upon the sacramental bread, the clergy stated that it was Christ's blood. In 1843 it came almost as an epidemic in Paris, where it grew more especially on the bread made and obtained in military bakeries.

The *Bacillus prodigiosus*, even when injected in large quantities into the blood of warm-blooded animals, fails to set up any symptoms.

There is a special bacillus which gives a *red* color to milk, whilst another peculiar bacillus communicates a *blue* coloration to milk.

THE USES AND EFFECTS OF SALT IN PRESERVING FISH.

The success and value of all fish-curing, whether by salting, drying, or smoking, consists chiefly in driving off the maximum possible advisable amount of water or moisture contained in the muscles or flesh and the skin of the fish operated upon.

As an antiseptic, salt acts in two ways. A saturated salt solution coagulates albumen, and hence bacteria (whose protoplasm is, of course, albuminous) cannot live. Most antiseptics have this power. Besides its antiseptic properties, sufficient salt prevents the continuation of life, which only occurs under more or less favorable chemical conditions. Thus sugar is a good food for bacteria. But an excess of sugar, as in concentrated sirup, makes bacterial life impossible.

Albuminous bodies are perhaps the best food for bacteria, yet, if concentrated by drying, those albuminous bodies keep indefinitely.

Small amounts of salt are food for bacterial life, partly because, perhaps like most vegetables, probably every animal requires chloride of sodium (common salt); and also partly because small quantities of salt tend to keep perishable articles damp. Moisture is favorable to fungoid life, especially if the salt contains magnesium chloride, which is almost always the case.

Concentrated chloroform is also an antiseptic, while small quantities of chloroform are alleged to favor bacterial development.

Experimental bacterial cultivations on salted and pickled meats show that the proportions of salt used in these food preparations have but very little destructive action on the putrefactive bacilli found in diseased meat.

Prof. Panum, in 1856, from artificial solutions of pickled salmon and salted herrings, subjected the liquids to prolonged boiling so as to destroy all living organisms and bacteria. Injected into animals, these boiled solutions produced poisonous effects, though in a less severe form than from similar liquid preparations which had not been boiled previously. Further, after filtering the fluid, then boiling it for an hour, evaporating to dryness the residue, which was next digested in absolute alcohol, he finally heated the resulting residue with boiling water. Nevertheless this watery extract was also poisonous.

Dr. Lauder Brunton, one of the grandest of our great scientists, has shown that the poison of putrid meat boiled for eleven hours and then completely dried at boiling heat, nevertheless retained its poisonous properties. Further he declares that the poisonous venom of serpents, though weakened, is not destroyed by boiling.

All this demonstrates and proves the vitality of poisons derived from putrid and other animal matter.

Brine-pickled herrings are alleged to have sometimes an ammoniacal smell due to the presence of trimethylamine. This compound is an ammonia where each equivalent of hydrogen has been replaced by one of methyl, common ammonia (NH_3) being converted into trimethylamine [$N(CH_3)_3$]. However made, trimethylamine has a strong fishy smell.

Especially if left for over twenty-four hours in a copper vessel, or in a copper vessel inefficiently tinned or enameled, salt fish has caused serious poisonous symptoms. On examination, the side of the vessel has been found green, and sometimes even a green jelly covering the cooked fish, which has become green by the infiltration into the fish's structure of a subchloride of copper. This must not be confused with the natural green bones of the kelp fish (*Coridodax pullus*), of the gar-pike (*Belone*) and its allies, nor with the red-boned mackerel used as a rat poison in Guadaloupe, a West Indian Island.

Some American packers of boneless fish are reputed to use a mixture of borax and common salt, in about the proportion of one thirty-fifth of the fish's weight, to prevent the preserved fish turning red.

COARSE CAVIARE.

In some parts of Russia the sturgeon roes are simply put in a more or less foul bag, with a strong brine. The mass is pressed by rapid wringing. It is next dried to let the superfluous brine drain off, placed in casks or cisterns whose bottom is perforated, where the mass is again squeezed or pressed with weights, which are not heavy enough to break the eggs. Sometimes the poorest description of caviare is trodden with the naked feet of the operators, whose squalid poverty and miserable filth are too frequently associated with disease.

During the awful plague in Astrakhan the worst and most fatal cases were usually among its fisherfolk.

Often rancid or decomposed caviare, with avoidable filth, is added to fresher eggs.

The cleanliness in the United States caviare factories is unknown in southern Russia, the home of astounding dirt and disease, augmented by the most hideous poverty and ignorance.

OBSERVATIONS.

Upwards of thirty years experience and observation at the chief fishing stations at home and abroad have convinced me that at too many of these food centers there is an increasing indifference to putrefactive filth. The avoidable but scandalously dirty condition of our British fish trade may again at any moment form a suitable "home" for the propagation and distribution of the bacteria of infectious fevers and diseases generally. Thus this preventable survival of the "fittest" filth, gives the bacteria of cholera, the plague, typhoid, etc., chances of infecting the public. Of course avoidable filth tends to preserve the specific agents—special bacteria and their products—which produce and propagate these hideous but preventable diseases.

The veteran scientist, Prof. Virchow, when sent as a young man to investigate an epidemic outbreak, then suggested as a cure municipal reform, with free action.

Prof. Koch, when recently reporting on the German cholera epidemic, considered it caused by contagion carried in a foul-water supply, which we know also introduced epidemic typhoid at Worthing, Arundel, etc., in 1893.

Cleanliness versus cholera and other filth diseases becomes more imperatively necessary as population and consequent overcrowding increases in all our large towns. Dirt, debility, disease, and death too often form a connected chain, in many cases alike avoidable and preventable by superior and scrupulous sanitation.

CONDEMNED MEAT, FISH, ETC., TENDERS.

The corporation of London again seeks tenders from "persons desirous of utilizing for manurial purposes the meat, poultry, game, offal, refuse, etc. (besides separate contracts for condemned 'fish,' its offal and refuse), condemned in the city of London as unfit for human food."

Now, presuming that at the hands of the corporation the condemned meat, etc., is first subjected to a thorough treatment with disinfectants, what use can such disinfected material be for manurial purposes?

The disinfectant is as injurious to the seeds and roots as it is to the bacteria of putrefaction and disease, including parasites and their eggs.

But it is unwise and unsafe to assume that the disinfection is complete. It is therefore a grave responsibility for the corporation to allow putrefactive animal matter and infected carcasses to be transported for miles in carts, especially through the narrow streets of its densely crowded colossal city.

Further, there is the danger of allowing partially disinfected material to be utilized as manure. Such a process only tends to spread infection widecast over fields, and possibly to infect, by parasitic and other diseases, the green food destined for man and for animals supplying his special food.

I have proved that the 1893 outbreak of epidemic cholera in the United Kingdom was due chiefly to the avoidable filth of the "fish" and its offal trades as carried on at Hull, Grimsby, etc. (By "fish" I mean aquatic and amphibian animals and their products used as man's food.) Bad "fish" caused epidemic cholera in St. Petersburg during December, 1893.

Again, the corporation sanctions the use of condemned food for manufacturing purposes. Of course it would be monstrous to imagine that diseased meat would be worked up into articles of diet, sausages, etc., or retailed for food to the poor. But that similar scandalous frauds have been practiced is well known to medical officers of health. For instance, in Paris, it is stated that till recently dead and diseased animals from their zoological gardens were regularly fetched away in carts, etc., without the knowledge of the zoological and other authorities in Paris. These miscellaneous mixed meats, under varied fraudulent names, were sold and eaten as food.

The working up of diseased products is a serious source of danger to those employed. It would be cruel, if not criminal, to allow diseased intestines to be made up into sausage-skins, and perhaps even eaten at civic banquets. But what supervision does the corporation exercise when once the putrid filth has left its carts? Does it see how the manufacturers use up these nauseous abominations and how and where this dangerous refuse is disposed of?

Surely public attention and action should force their "sanitary" servants, the municipal authorities of the United Kingdom, to avoid these peculiar and possibly poisonous proceedings. Such paid professional bodies should forthwith build and employ properly constructed local *furnaces* as the most efficient and economical hygienic means to destroy condemned animal matter, including "fish," its offal and refuse.

RINGS AND ROTTEN FISH.

The Billingsgate ring not alone chains the crushed and indebted fishermen of the United Kingdom in cruel, chronic poverty; it not alone makes the consumer often pay from 600 to 800 per cent or more for the fish than is given to the fishermen, but it provides the public with fish generally more or less stale or decomposed, and sometimes even putrid and poisonous.

To diminish the market supplies of "fish," so as to artificially keep up the high price of fish, this ring gets fish destroyed at various places along our coast. This Billingsgate ring is the ruin of our national coast and inland fisheries and fishing industries. Already in 1749 it extinguished the Westminster fish market. It caused the failure of the old Hungerford fish market. It strangled the Columbia market even when subsequently taken over conditionally from Lady Burdett-Coutts by the corporation of the city of London. Her ladyship is reported to have lost a large fraction of £1,000,000 sterling, partly because of the unscrupulous opposition to her benevolent schemes by the Billingsgate ring, and also because her public fish market was placed inland without any approach by water. It snuffed out Mr. Plimsoll's fish market at the "Elephant and Castle." It has turned the corporation fish markets in Farringdon street into trading fiascoes. By its clever combination it boycotts and starves Shadwell fish market.

Save a few favored fortunate virtual monopolists, the fish-traders of the United Kingdom are working hard to gain little or nothing, as the legitimate profits of their toil and trouble tend to tumble into the tills of the Billingsgate ring, who are assuredly remarkably shrewd "business men."

In 1880, before Mr. Spencer Walpole, by direction of Sir William Harcourt, the home secretary, holding an inquiry on alleged Billingsgate abuses, the late George Stevenson, a Billingsgate fish salesman, and a popular member of the markets committee of the corporation, thus expressed himself in his evidence:

> It would be better that all London should sink than that Billingsgate market should sink. Billingsgate is one of the grandest institutions of the country.

The Billingsgate ring, by a shrewd system of cruel, crushing mortgages on the *uncaught* and the caught "fish," enslave and impoverish the indebted fishermen. According to Cahill's evidence before the corporation 1881 fish inquiry:

> The practice in Billingsgate market is that its ring realizes the highest price it can, and returns the sender *what is expedient*, or what may be agreed on among its members. This ring very often, after agreeing on the price to be sent to the senders, so distrust each other that they exchange account sales inclosed in open envelopes, so that A reads, seals, and posts B's sales, and *vice versa*.

The charters for our fresh-food markets were granted to directly bring the producer and public together, but are now usurped by a handful of capitalists, who have cleverly cornered the public markets and their entire fresh-food supplies, so as to sweat the producers, semistarve the masses, and overcharge the classes.

Cobden's free-trade principles have been so engineered that the producer gets no profit because the middlemen, monopolists, or cuckoos of commerce, gain all.

The Billingsgate ring excludes the public, the fishmongers, and the costermongers from purchasing "fish" except from the ring, who cling to perpetuating bacterial Billingsgate with all its avoidable abominations and augmenting abuses. Hence, stale fish continues at famine prices instead of cheap, fresh, healthy, or imperishable fish.

Every day of the year 2 pounds of bled, gutted, cleaned, dry-air-frozen (imperishable) fresh herrings (about six fish) could be profitably retailed by costermongers for 1 penny, or 2 pounds of sprats for 1 halfpenny.

CHEAP FOOD OR WANT.

Want or semistarvation for the masses, the impoverishment of many capitalists and manufacturers, and agitations leading possibly to riots, appear to threaten, unless cheap, healthy, abundant food is speedily secured for our poor and comparatively poor. Man, by labor or inherited labor called wealth, must get fed regularly and fed cheaply. His digestion requires a wide and varied diet. In our cold, damp climate, where sunshine is comparatively rare, every man should obtain at least one daily meal of fish or meat.

Owing to faulty distribution and preservation, much of the fish and meat consumed by the poor is often wretchedly inferior and exorbitantly dear. Hence, perhaps, their excessive tendencies to alcoholic drinks and tobacco, which at least please the palate.

The producer provides cheap, excellent frozen meat, poultry, and game which too rarely reach the consumer except when sold as and at the high prices of home bred, fed, and killed animals. Legislative interference should prohibit such fraudulent trading. Our manufacturers will soon be unable to compete with foreigners, who obtain cheaper labor because of cheaper food. Hence the land, buildings, and plant of the British manufactories will suffer increasing depreciation; their laborers and those dependent upon the earnings of the laborers will find their occupation gone.

Without the intervention of middlemen, by means of retail stores and costermongers for the poor, the producer should sell fresh food direct to the consumer.

Inferior and bad feeding injures a nation's growth, health, strength, and digestion, producing passing or permanent derangement and disease. Being thus enfeebled, the laboring classes do diminished and inferior work, thereby inflicting direct but an avoidable loss upon their employers. Hence the question of cheap, healthy, abundant food should be carefully considered by Parliament and the municipal bodies.

The laborer's chief daily item of expenditure is for food for himself and his family. Regular, cheap, healthy, fresh, imperishable food, and other foods unadulterated and undiluted, would *virtually increase the laborer's wages.* The present unnecessarily exorbitant price of food and its inferior quality are the chief factors which often lead to disputes between labor and capital, too frequently terminating in strikes.

GLUTTED MARKETS.

Glutted markets, as applied to fresh food, especially "fish," is a misleading trade term. Thus, because of its diminutive area, together with its inefficient road, river, and railway approaches, and owing to its restricted market hours, Billingsgate is too easily and frequently glutted with fish. No one has ever yet heard of London and the country generally being glutted with fish. On the contrary, whilst Billingsgate partly supplies upwards of 10,000,000 people at home and abroad with fish, many British fishermen, unable to get their fish to market, either have practically to throw it away to manure the land or, in other cases, abstain, while semi-starving, from fishing, because of their having no market for their produce.

The supply of imperishable fresh fish is independent of fogs, calms, and storms, which now too often cut off fish supplies.

The introduction of imperishable fresh fish would lead to a colossal lucrative export trade.

SALINE SODDENING OR MEAT "KOSHERING" BY JEWS.

This consists in three processes:

(1) *Soaking meat in fresh water.*—With the aim to absorb all available contained blood prior to cooking, orthodox or conforming Jews keep a special cookery pan, in which for about half an hour they soak their meat (killed after their own ritualistic practices) with a view to drain off all available blood. After half an hour this fresh water becomes a pink red color, which under the microscope reveals blood cells and hæmoglobin (red coloring matter). Chemical tests discover considerable traces of albumen and some alkaline salts. The varying conditions and circumstances make a quantitative analysis impossible as a practical average.

(2) *Slight salt-sprinkling.*—Next, the meat is slightly sprinkled with salt all over its surface and then placed on a perforated board, where it remains for an hour. The salt becomes of a pink color. On being dissolved in distilled water blood-cells are discovered in the salt mass by the microscope. The Jews throw this red and used salt away. They keep the soaking pan and perforated board scrupulously clean.

(3) *Salt washed off.*—Finally the salt is washed off the meat in a stream of running fresh water, as from a tap. Collecting this water, it is pink-red in color, showing under the microscope numerous red and white blood corpuscles, some sarcous elements (portion of muscle fibers or flesh) and some fat cells. Chemically it contains more albumen than the fresh water in which the meat had been previously soaked for half an hour.

These three processes constitute the koshering of food according to the practice of orthodox conforming Jews. By removing some of the albumen and alkaline salts, in every case it must tend to make the meat of poorer quality. Where the meat is stale or decomposed, adding the moisture by soaking, damp salt and washing would promote putrefaction. Hence chemically, clinically, and economically it is a practice which is diametrically opposed to modern science and household thrift.

In the Jewish or kosher meat trade its authorities are said to insist that after meat has been killed for three days, or at the expiration of the 72d hour, it shall be sprinkled with a saline solution to make the meat again "kosher" or ritualistic. This has to be done with meat prior to its being refrigerated for export as "kosher." It has been falsely alleged that this saline soddening has made such refrigerated meat decompose and be unfit for food. Of course this is only a trade trick to exclude foreign and colonial meat.

36.—RECENT EXPERIMENTS IN STURGEON HATCHING ON THE DELAWARE RIVER.

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The region of the Delaware River near its mouth has long been the seat of an extensive fishery for sturgeon (*Acipenser sturio*). At Delaware City, Del., the great number of fish brought in daily to the wharfs during spawning time provides an opportunity especially favorable for experiments in artificial propagation. The studies by Prof. Ryder (published in the U. S. F. C. Bulletin for 1888) were here carried on in 1888, and during the present season this station was again selected for experiments to be made in behalf of the U. S. Commission of Fisheries.

At the time of the writer's visit the fishermen were bringing daily to the slaughtering wharfs from 50 to 100 fish; and among these (May 16, 17, 18, 1893) a number of spawners were taken. There was thus abundant material for purposes of experiment. In the following paper the results of these test studies, in their bearing upon practical sturgeon-culture, are briefly reviewed.

Fertilization.—The fertilization of the eggs, as known from former experiments,* is easily accomplished. The milt and roe appear to even retain their capability of fertilization under conditions seemingly very unfavorable. Ripe fish when brought into the docks had been out of the water at least several hours; no precaution had been taken to insure their careful transportation, and they were usually near the point of death. In one case eggs were successfully fertilized which were taken from a fish apparently lifeless. The milt appears to remain active as long as a quarter of an hour after the fish had been slaughtered.

In the mode of fertilization care in details appears to be needless. Eggs from ripe fish are readily fertilized whether extruded by pressure or obtained by excision. In the latter case there is apparently no preference to be given to eggs from different ovarian regions. Excision is certainly the more speedy and convenient method. The eggs may be received with equal success in vessels earthen, metal, or wooden. Especial cleanliness is not vitally essential—in one case eggs were fertilized in an earthen bowl from which a fixing solution of concentrated acetic-sublimate had been hastily rinsed.

Milt may likewise be taken as well by excision as extrusion. In case the fish be not actually "ripe" sufficient milt for a fertilization may often be obtained in a pipette after repeated body pressure. Milt may be collected in vessels clean, soiled, or rusted, and will retain its activity (out of water) for at least six minutes. Obtained by excision the milt may be separated from the fragments of cut testes by coarsely straining through cloth. For convenience in handling, it was found that the milt might best be secured and retained in a long rubber-bulbed pipette.

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*In the United States those of Seth Green, 1875 (Fish Hatching and Fish Catching, Rochester, 1879); Prof. Ryder, 1888, and William Lanz, 1890 (Ohio F. C. Report).

If untouched by water the eggs remain capable of fertilization for several (five) minutes. Details in the mode of introducing the milt seem of but little importance. No better results followed the introduction of milt directly from the living fish than of that strained from cut testes and retained several minutes in pipette. A few drops of milt were found to fertilize about 2 liters of eggs.

In the experiments, running water was in some cases added to the egg mass at the time of fertilization, in others as long as ten minutes afterward; in all cases were results approximately the same. Within from twenty to thirty minutes the eggs have become viscid and "set."

Under conditions of natural spawning it seems probable that the eggs are fertilized at extrusion, since experiment failed to fertilize eggs that had been immersed in water about half a minute. This spawning condition is further attested by the scratches and abrasions noted on the abdomens of spent fish, both male and female.

Difficulties in sturgeon-culture have usually been reduced to three: (1) That of obtaining ripe eggs and milt simultaneously; (2) that of imperfect means of aëration of eggs, and (3) that of inroads of fungus. It is evident that by careful experimental study the dangers of malaëration and fungous growth might be reduced, if not largely obviated. To these problems the attention of the writer was especially directed.

Difficulty of aëration.—Sturgeon eggs have proven difficult to handle on account of their viscid character. Shortly after artificial fertilization the eggs stick together in a glue-like mass; this, speedily hardening, forms a compact egg mass, whose dense jelly-like matrix the culturist finds does not permit the inner and innermost eggs to be sufficiently aërated. Dying in consequence, these become the cause of the loss of the intimately connected surrounding although better aërated eggs.

On the natural spawning-grounds this harmful condition does not, apparently, maintain. The eggs, fertilized and becoming viscid, appear to be drawn out into stringy clusters or ribbons, attaching at all points to submerged objects. Sticks, water weeds, fish nets, and especially brush, spread over with a thin layer of sturgeon eggs, are well known to the fishermen. Egg-attached objects, moreover, it is generally noted, are found only in deeper, usually channel waters.

Favorable aëration, as suggested by natural conditions, seems accordingly to be insured by the disposition of the eggs in thin layers and by a plentiful water supply. To imitate these natural hatching conditions in a way practicable for large numbers of eggs is clearly the bourne of the culturist. To attain this end, however, is not his easiest task. The eggs, becoming viscid speedily, must be attached to the hatching devices with the greatest promptness. The hatching trays must be prepared for immediate use, and the eggs must simultaneously be spread over them in a single layer. Otherwise, all eggs becoming "set" at the same moment, those that remain unspread must, in their clustered condition, be inevitably lost.

Aëration seems to be especially concerned with three cultural details: (1) The character of the egg trays; (2) the mode of egg attachment, and (3) the means of securing water circulation.

1. The shallow trays to which the eggs are affixed have, as far as the writer can find, been constructed either of fine metal gauze* or of cheese cloth.† In the present experiments the use of a coarse-meshed "mosquito netting" was found to give most satisfactory results. Of a tray bottom of this material the perforations are sufficiently large to admit an egg, but not so large as to permit it to pass through; a tray properly prepared retains a single layer of eggs, which may be aërated as conveniently on the under as on the upper side.

2. In former experiments the eggs, becoming viscid, appear to have been lifted from the water, spread upon the trays, and retained thus until their attachment. In trials made at the suggestion of Mr. Pancost, of Delaware City, the eggs were spread upon immersed trays. Under water the eggs are easily handled, flowing smoothly over the netting tray, and by careful tapping of the tray frame may be made to assume a single layer. Placed on the tray ten minutes after fertilization they become firmly attached within twenty minutes.

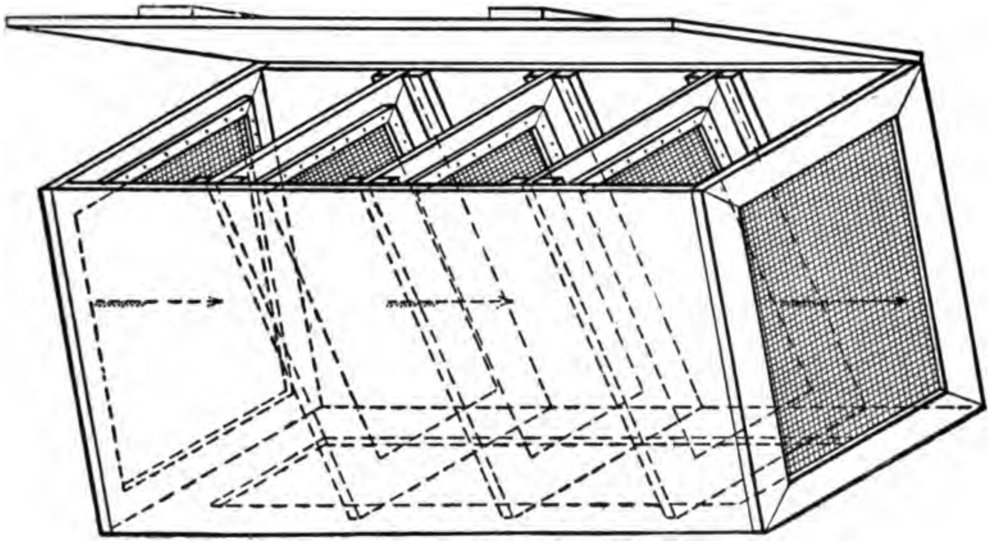

Diagram of floating case used in sturgeon hatching.

3. To secure the free circulation of water necessary to the hatching process, the egg trays are arranged in stout wooden cases, which float in the current or are sunk (Glückstadt, Elbe) in deep water. Bottom and two sides of the cases covered with metal gauze permit a free passage of water current. In the present experiments the floating hatching-case differed from any of which the writer is aware in the following regards: It was nearly as deep as wide. By this means the hatching-trays might be placed almost vertically, to thus take advantage of the water current and at the same time economize space. As many as four trays to a case were successfully employed; these, held in position by cleats, were directed slightly downward, to guard against deposits of sediment. The incoming current was directed against the under side of the tray.

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* Experiments of Green and Lanz.

† Prof. Ryder, U. S. F. C. Bulletin, 1888, p. 272.

The problems of aëration seem closely connected with those of fungous growth, as may be seen in the following paragraphs:

Inroads of fish fungus, Achlya.—The greatest difficulty encountered by Prof. Ryder in his experiments at Delaware City appeared to be due to fungous growth. This would be found to arise at various points of the hatching-tray during the first 48 hours of hatching, and would gradually spread its velvety encasing over and stifle the entire egg mass. For success in hatching, water sterilization was then suggested, the fungous spores to be removed by use of either filters or heat.

The effect upon fungous growth of more perfect aëration and increased salinity of water, however, had not been positively determined. And in the following experiment the writer aimed to reconsider these matters, hoping that favorable results might suggest a simpler and less costly means of evading fungous growth.

The results of Prof. Ryder had been obtained in a small fresh-water pond emptying through the river bank directly into the Delaware; the hatching-cases had been placed in a sluiceway through which water was constantly escaping; yet in spite of this current, fungous inroads had here destroyed all but a few of the fertilized eggs. It was the plan of the writer to array a line of hatching-cases from this shore point near the mark of low water out as far as the edge of the channel in deep water. By this means (the cases to contain eggs in every way similarly conditioned) the effects of differences of salinity, aëration, and silt deposit upon fungous growth seemed most likely to be understood. Surface waters of mid stream, stronger in current, would naturally be better aërated and more devoid of silt than marginal waters. In channel, moreover, the water density was noted at 1.007 (sp. gr.).

The success of the experiment seems clearly to indicate the means that may be here taken to obtain practical results. The eggs in strong current, in salter and less silty waters were practically exempt from attacks of fungus; those in marginal waters speedily perished (see table). It would in fact seem to the writer that the fungus is rather a consequent than a prime cause of egg destruction. That it is lacking under the natural conditions of sturgeon hatching is a fact not the most remarkable, and that it may be obviated in artificial processes by imitation of the natural hatching conditions seems the simplest plan of cultural procedure.

No. of case.	Location.	Percentage of eggs destroyed by fungus.			
		Second day.	Third day.	Fourth day.	Fifth day.
I	At outlet of fresh pond, as in experiments of Prof. Ryder	100			
II	At stake near line of low water	60	100		
III	At wharf sluice a rod farther out	20	80	100	
IV	At wharf end a rod farther out		20	50	60
V	In deep water in current at breakwater		5	5	5

In the above results the problem of hatching sturgeon eggs is doubtless intimately conditioned by water current, by silt deposits, by salinity of water. To determine to what degree each of these factors is contributive to success would doubtless be very difficult. In the case of the common anadromous sturgeon (*Acipenser sturio*) a slight degree of brackishness of water might be regarded as a favorable, if not a necessary condition, were it not that the eggs of this species have been repeatedly hatched in water that was absolutely fresh (New Hamburg, N. Y., Seth Green; Delaware City, Del., Prof. Ryder; the Elbe). Current, on the other hand, could not have been alone an essential condition, since in the fresh sluiceway at Delaware City, in the experiments of Prof. Ryder, a circulation maintained stronger undoubtedly than in channel waters. Nor could the effect of silt be regarded as alone the unfavorable element; quantitatively in mid stream—especially of sturgeon waters—an amount of sediment might be expected greater doubtless than a neighboring spring-fed pond. Mode of temperature variations might, again, be looked upon as of problematic value. To what degree, then, is the sum of all conditions to be regarded as essential for success in sturgeon hatching? In theory the problem is assuredly more troublesome than in practice.

As to obtaining simultaneously spawning fishes, male and female: In the event of extensive culture this difficulty is one that in the opinion of the writer could not be regarded as of serious weight. In a favorable locality each season brings a number of spawners to the wharfs of the fishermen, and with a regularity of occurrence that appears remarkable. In a letter to the writer, Mr. Reuben Anderson, of Delaware City, well known as a careful observer of the habits of the sturgeon, predicted *to a day* the appearance of spawners. He afterward stated that the "run" of fish,* though brief—often not longer than a single day—might, in his long experience, with every possibility be depended on.

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* A breeding habit of the sturgeon Mr. Anderson discussed with the writer, seems for cultural purposes of the utmost significance. The earliest fish in their passage up the stream spawn farthest from the river mouth, the next school in a locality not as distant, and the later fish in the lower stream regions. This zonal distribution in spawning seems attested by the character of fish as taken in their journey past a single shore front; the earliest are uniformly "caviar fish" (i. e., of immature ovaries); later are taken "runners" (i.e., ripe fish); and at the close of the spawning season none but "slunkers" (i.e., those having spawned).

37.—THE FISHERIES OF CANADA.

BY L. Z. JONCAS, M. P.

All those who have written on the fisheries of Canada have agreed to say that they are inestimable; and, as a field for industry and enterprise, they are inexhaustible. Besides their general importance to the country as a source of maritime wealth and commerce, they also possess a special value to the inhabitants. The great variety and the superior quality of the fish products of the sea and inland waters of these colonies afford a nutritious and economic food, admirably adapted to the domestic wants of their mixed and laborious population. They are also in other respects specially valuable to such of our people as are engaged in maritime pursuits, either as a distinct industry or combined with agriculture. The principal localities in which fishing is carried on do not usually present conditions favorable to husbandry. They are limited in extent and fertility and are subject to certain climatic disadvantages. The prolific nature of the adjacent waters and the convenience of their undisturbed use are a necessary compensation for defects of soil and climate. On such grounds alone, the sea and inland fisheries to which British subjects have claims on this continent are of peculiar value.

From whatever point of view we may regard them, the teeming waters of the British American Possessions, and those which form their great lakes and magnificent rivers, must be reckoned as a national property, richer and more perpetual than any mere estimate in money can express. It is in the highest degree satisfying to find that Canadians are becoming every year more and more alive to the vast importance of their fisheries, and that they are now more than ever anxious to preserve them as the finest material portion of our colonial heritage.

Dr. George Brown Goode, one of the most prominent citizens of the United States, whom I had the honor and pleasure to meet in London at the International Fisheries exhibition, in one of his speeches at the Fishery Congress in connection with this exhibition referred to the immense growth of the Canadian fisheries during the last ten years. He declared that in the course of his own studies he had occasion each year to peruse the Canadian reports, and had been perfectly amazed at the rapidity with which this industry had been developed. In fact, if we consult the statistics so carefully collected every year by our fishery officers, these official figures will show that the value of the Canadian fisheries, which in 1870 was only $7,573,000, had doubled during the succeeding ten years, and amounted in 1880 to $14,500,000; and if we open the last official report published by the Department of Marine and Fisheries, we shall see that the same fisheries produced in 1892 over $20,000,000.

Although our system of inspection is effective, although the organization of the outside service of our department of marine and fisheries and our method of collecting fishery statistics are given as models to other countries, yet they are susceptible of many improvements. It is easy to understand that in such an extensive country as Canada, where every settler has facilities for fishing, it is utterly impossible for our statisticians to impart a mathematical precision to their reports or to give accurately the value of the home consumption. The $20,000,000, mentioned above as the value of the Canadian fisheries in 1892, can not be anything else than the value of the fish prepared for exportation or sold on the Canadian markets. In that amount I do not include the $5,000,000, the approximate value of the fish caught and consumed by the native population of Manitoba, British Columbia, and the Northwest. And in the other provinces of the Dominion, with a population of over 4,000,000 inhabitants, for whom fish is one of the principal articles of diet, the estimated value of fish consumed is $12,000,000. Adding the value of fish cured for the trade and that of fish captured for local consumption, we have, for 1892, a total of $37,000,000. These figures give an idea of the immense richness of the Canadian waters.

Every country of the world having waters of any extent understands what an important contribution fisheries are to the national wealth and encourages by every possible means those who carry on this industry. Large sums of money are spent every year by capitalists in the building of continually improved fishing craft and gear, and governments are spending millions in the construction of piers, breakwaters, wharves, and other improvements for the advancement of the fishing industry. Fishery bureaus, headed by the most eminent, influential, and practical men, are formed to seek for the best means of rendering the fisheries more and more productive, and this exposition brings an additional proof of the interest taken by all in the progress of the fisheries and the welfare of the fishermen.

I am happy to be able to state here that, owing to the encouragement lately given to them by our government, and especially by our able and energetic minister of marine fisheries, Sir Charles Hibbert Tupper, the Canadian fisheries are rapidly progressing. Fishing-craft building has advanced rapidly, and the swift schooners of our maritime provinces can already compete fairly with American fishing vessels, reputed the best of their class in the world. Steamers, which are now used in the fisheries on our lakes, will doubtless be seen soon among the vessels used for the working of our most important sea fisheries. Considerable sums of money are spent by our government on the building of harbors of refuge and lighthouses for the guidance of the fishermen. A large sum of money is distributed every year among our fishermen as premiums, and our public men are willing to continue to help the advancement of an industry which for the future of the Dominion is so necessary and important.

The incalculable importance of such invaluable fisheries in colonization, in the development of commerce, in adding to the country's food produce for home consumption, and for the training of skilled seamen for naval and merchant marine, are points which the histories of all great maritime nations amply demonstrate. The histories of the United States, France, Holland, Great Britain, are striking illustrations of the vast national benefits derived from the prosecution of sea fisheries. What but the rough experience of British and United States fishermen in prosecuting their labors on some of the roughest coasts of the world has made their skill and bravery? It is rough experience that makes a sailor, and it is just such experience that has enabled the seamen of the maritime provinces of Canada to take a first place for skill and coolness among the other sailors of the world.

Our most important fishing-grounds.—The fisheries of Canada may be divided into two great classes, the deep-sea fisheries and the fresh-water or lake and river fisheries. We shall give the precedence to the former as being the most important. Only about half of our 5,000 miles of seacoast has till now been properly worked. We do not know yet all the riches of the British Columbia waters, but can infer from reading the official report that they are teeming with a great variety of commercial fishes.

Our most important deep-sea fishing-grounds are the Atlantic coast of Nova Scotia, from the Bay of Fundy, around the southern part; around the coasts of Cape Breton, New Brunswick, and Prince Edward Island; embracing the Bay of Chaleurs and the Gaspe coast, and extending to the island of Anticosti, Labrador and the Magdalen islands. There is probably no part of the world where such extensive and valuable fisheries are to be found as within the Gulf of St. Lawrence. Nature has bountifully provided within its waters the utmost abundance of those fishes which are of the greatest importance to man, as affording not only nutritious and wholesome food, but also the means of profitable employment.

The cod fishery.—Of all the deep-sea fisheries of Canada, the most important is the cod fishery, which furnishes employment to thousands of men and contributes most largely to our exportation trade. It is one of the leading industries in Nova Scotia, New Brunswick, and the lowest part of the Province of Quebec, and last year it contributed over $6,000,000 to our export trade. I will not attempt to give you the history of the Canadian codfishing; it would take too much of your valuable time. I will content myself with a brief summary of the way this industry is carried on.

The cod appears on the Canadian coasts at uncertain dates, generally between the middle of May and the beginning of June, sometimes in the latter end of the month of April. Local variations in the time of its arrival, amounting to days and even weeks, frequently occur, and these are dependent on the temperature, which determines the movement towards land of the various forms of marine life on which the cod feeds. It has some favorite spots, where it is found in greater quantities. These are the places which present the best advantages for the preservation and hatching of the spawn. Having deposited its spawn, it withdraws to shallow places, called banks, where it always finds food in sufficient quantity to satisfy the well-known voracity of its appetite. About the month of December the codfish appear to leave the shallow soundings and banks inshore and go farther out to sea.

The codfishing season varies with the different provinces, beginning earlier in Nova Scotia and New Brunswick, where the climate is not quite so severe as in the province of Quebec. From April to November, inclusive, may be given as an average time. The arrival of the cod on the coasts in the spring is heralded first by the herring, and secondly by the capelin. The latter is a small fish, the favorite of the greedy cod, and therefore the best fishing bait. In every large fishing establishment, during all the month of June, two or three boats, each of them manned by 7 men called seiners, are employed day and night in going about the coast in search of the capelin. When they meet with a shoal of these fish they cast the seine, load their boat, and hasten home to distribute these little fish amongst the fishermen. Each codfishing boat receives an equal share of the fish thus brought by the seiners. Vessels engaged in fishing on the banks run into the harbor at intervals for fresh supplies of capelin as bait, which they preserve in ice.

In some parts of the Dominion a considerable quantity is dried, packed up in small boxes, and sent to some of the United States markets. After the capelin has disappeared from the coast, about the end of June, the launce, the herring, the mackerel, the squid, the smelt, clams, etc., are used as bait for the cod.

Our cod being mainly taken by hand lines and bultows or set lines, the cost of bait for codfishing is great. It is certainly not an exaggeration to estimate the actual cost of bait at one-fourth of the value of the cod taken. Besides this, much time is lost every year during the fishing season, owing to the want of fresh bait, which is not always easily procured and which is essential to good fishing. Hence anything that should economize the cost of bait and save time would be both desirable and important. Norway, the most important cod-producing country of Europe, and our chief rival in the cod markets of the world, has in recent years greatly improved her modes of fishing, her fishermen using gill nets to a large extent, with great success.

The cod fishery is carried on in Canada, either in vessels of a tonnage from 60 to 100 tons on the great banks or in open boats at a few miles from the shore. Nova Scotia and New Brunswick seem to have the monopoly of the fishing in large decked vessels, and I am happy to say that naval architecture has improved very much, during the last ten years, in these two provinces. This improvement in the dimensions and lines of their vessels has enabled their fishermen to increase their annual catch of fish considerably.

Vessels employed in codfishing are manned by from 10 to 13 men, according to tonnage. Generally the owner of the schooner, who also supplies the men with the necessary fishing tackle, receives half the catch, the fishermen retaining the other half. When the vessels have reached the fishing-grounds they are anchored, by hemp or manila cables, in from 15 to 50 fathoms of water. Bait is obtained by spreading nets in the sea at some distance from the vessel, and the fishing is then begun, with bultows or long lines, and carried on by night as well as by day, in spite of wind and storm, until the hold of the vessel is filled up with fish all split and salted. Then the vessel returns to port, the cod is landed, washed, dried, and prepared for exportation.

Fishing in vessels is more expensive, but also more remunerative, than fishing with open boats along the shore. Cod taken on the banks are larger and finer in quality than those fish taken along the coasts. An average of 30 bank cods, when dried, makes a quintal, and it brings a higher price than the shore fish.

In the province of Quebec and in Prince Edward Island the cod fishery is still almost universally carried on in open boats, in the neighborhood of the coves and bays where the fishermen reside. In some parts of the province of Quebec, however, fishermen venture with their open boats to 20 and 30 miles from shore. These boats are built by the fishermen themselves. They vary in dimensions from 20 to 40 feet keel, with a breadth of beam from 6 to 10 feet, according to the use they are intended for. They are very sheer built, and their clinker work is usually of cedar. Pointed at both ends, their rigging consists generally of two sprits or gaff-sails, some of these intended to fish on the banks being schooner-rigged. They are comparatively light, in order to be easily hauled up on the beach in stormy weather; are good sailers and behave wonderfully well at sea. Yet, although good sea boats and splendid sailers, manned by fishermen whose intrepidity and skillfulness are well known, these boats are too small to enable our fishermen to carry on codfishing upon as large a scale as it might be done. The fishermen of Quebec and Prince Edward Island, with their small boats, being too often obliged to run before the storm and leave the fishing-grounds when they are sure of a good catch, in order to save themselves from being caught away from land by heavy gales, lose every year much precious time during which the fishermen of Nova Scotia and of New Brunswick reap an abundant harvest. The reports on the fisheries of the last few years show a noticeable diminution in the quantity of fish caught by the fishermen of the province of Quebec, and this deficiency was due mainly to the frequent storms which raged in the Gulf of St. Lawrence during the last few years, and also to the absence of harbors of refuge in this part of the Dominion.

Our principal markets for dried and salted codfish are Italy, Spain, Portugal, Brazil, the British and Spanish West Indies, and the United States.

The finest cod in all America is cured on the coast of Gaspe, in the Province of Quebec, where the effects of the mists generated by the Gulf Stream are least felt. It is well known in the markets of Spain, Italy, and Brazil, where it is generally sent, the large fish going to the Mediterranean countries in bulk in vessels from 100 to 300 tons and the small fish to Brazil in drums containing 128 pounds.

During the time that the fish is exposed on the flakes to dry, if the weather is fine, the sun shining, the westerly winds predominating, cod is easily cured and made of fine quality; but sometimes easterly winds prevail, rain lasts for weeks, and in spite of all possible care and precaution it is inevitably spoiled. So, before sending it to the markets, the fish is carefully culled, the greater part of the best quality being sent to Europe and Brazil and the inferior to the West Indies. Nova Scotia, New Brunswick, and Prince Edward Island export chiefly to the West Indies, United States, and Brazil; Quebec to Brazil, the Mediterranean countries, and the West Indies.

The cod is the most useful of all fish; no part of it is valueless. Oil is taken from its liver; the head, tongues, and sounds form a good article of food; the offal and bones, when steamed, dried, and ground, are converted into very good manure, equal as a fertilizer to Peruvian guano; the roes are a splendid bait for the sardine fisheries of France and Spain; and from the swimming bladder isinglass is made.

The herring fishery.—The sea fishing next in importance to the cod fishery in Canada is the herring fishery, the value of which, without taking into account the local consumption and the quantity used as bait for the cod fishery and for manure in many parts of the Dominion, was, according to our last statistics, represented by the sum of over $2,000,000. This amount is a large one, and the result seems handsome, but it is certainly not in relation with the abundance of this fish in Canadian waters. The herring fishery is far from getting here all the attention it deserves; and I might even say that we have no regular herring fishery in Canada. It is true that in Nova Scotia, New Brunswick, and Prince Edward Island schooners are especially fitted out for this fishery; that it is regularly and intelligently practiced by a large number of men from those provinces, bringing them handsome returns; still all these endeavors, although very laudable, are nothing but isolated undertakings.

It will perhaps surprise a good many of my hearers to learn that the whole of the Province of Quebec, possessing 10,000 fishermen, 1,100 miles of maritime coasts, numerous bays far-famed for the abundance of herring repairing to their waters, does not annually export 2,000 barrels of this fish. Although they could derive immense benefits from the working of the industry, the Quebec fishermen are satisfied when they have taken enough for their own consumption and for the wants of the cod fishery.

The reason of this apparent neglect lies in the fact that the province of Quebec capitalists give all their time and attention to the cod fishery. Nevertheless, it is almost impossible, without seeing it, to form a correct idea of the immense quantity of herrings that visit the coasts of the province, especially in the spring during the spawning season. Their compact masses cover thousands of acres of the sea, so that if the fishermen were provided with the necessary fishing appliances, if they had a ready market, they could easily in a few days, even before the beginning of the cod fishery, catch enough herring to realize thousands of dollars.

I assert with confidence that if in Canada this industry were conducted on a scale proportionate to its importance and the abundance of herring in our waters, if companies were formed to provide our fishermen with boats and fishing implements like those used in Europe, our herring fishery instead of two would bring every year five or six million dollars. Nor are the markets wanting for this fish, which is cheap and can be bought by the poorest; for besides our own market we should have those of the United States, of England, Germany, and the West Indies. The population of Europe and of South America is growing rapidly, and the products of the fisheries of these countries are far from being sufficient to meet the demand. We have there an almost unlimited market for our pickled fish, if carefully prepared and packed.

Mackerel fishery.—I am happy to say that the energetic and progressive fishermen of the United States have no longer the almost exclusive monopoly of mackerel fishing in Canadian waters—a monopoly that they have enjoyed for a number of years. Wearied with beholding the success of the Gloucester fishermen, who year after year came to our doors to reap an abundant crop, the fishermen of Nova Scotia and New Brunswick set to work and have succeeded very well. They are to-day carrying on mackerel fishing on a large scale and deriving good profits from it. They can show a fine fleet of vessels so improved in symmetry as to bear fair comparison with the American schooners, which are reputed to be the finest vessels and the best sailers of their class in the world. Nor are they merely owners of splendid vessels fitted out with the utmost care; they have adopted the most modern fishing appliances, and are prosecuting this industry with great tact and intelligence; for the mackerel fishery is difficult, precarious, and uncertain. A schooner may cruise in the gulf for a week, without taking a fish, while another gets filled in a fortnight or less. It requires, therefore, to be carried on with sagacity and perseverance—two qualities which distinguish the fishermen of our maritime provinces; but then it is generally successful, brings in large profits, and is certainly worthy of the attention of the capitalists.

The tourists who, during the dog days, run away from the heat of our cities to breathe the pure and vivifying air of the Gulf of St. Lawrence and make the journey by water, have often, in the course of their visits to the maritime provinces, met with fine mackerel schooners and mistaken them for a small squadron of yachts, so beautiful are their masts and sails, so neat and clean are they kept. But, on a nearer approach, this is found to be an error; for on the decks of these vessels are to be seen crews of from 10 to 20 men, all occupied either in catching fish, in repairing fishing implements, or in splitting and salting the fish that has been taken; and what is more striking is the order that reigns on board these schooners, whose decks and holds are almost always full of fish, fish barrels, salt, etc. These schooners are generally of from 60 to 100 tons burden. They have little depth of hold, great breadth of beam, rake very much fore and aft, and carry large cotton sails which enable them to sail fast even with a light breeze. Their decks are roomy, and on them the whole work of salting and barreling is carried on. Mackerel is met with off the coast of Nova Scotia, in the Bay of Fundy, and in the Gulf of Canso; but nowhere is it more plentiful than in the Gulf of St. Lawrence, off the coast of Prince Edward Island, and in the numerous coves and bays formed by the Magdalen Islands.

The mackerel is one of the most valuable fish visiting the Canadian coasts. A good proportion of our catch is sent fresh to the markets, some in tins, and the largest quantity pickled and packed in barrels. Our best market for either fresh, canned, or pickled mackerel is the United States, although Great Britain and the West Indies also buy some of it. From the last statistical returns we see that the mackerel fishery produced $1,550,000, but it could certainly afford employment to many additional vessels and employ thousands of additional hands.

The lobster and oyster fisheries.—It seems to be the tendency of this age of competition to overdo any business which promises to be lucrative. Not more than ten years ago, when the retail price of lobsters was two or three for a half-penny, a New Brunswicker came to Prince Edward Island and commenced the business of preserving in tins. Attracted by his success, a few other persons engaged in the same pursuit. The business gradually augmented until three or four years since, when it became endued with much more life, and has, at length, sprung into great dimensions. We have now no less than 662 canneries in operation, and last year this industry contributed $2,000,000 to our export trade.

I need hardly mention here that this industry is of considerable importance in the general economy of the Dominion. Every one understands that the erection of buildings, tin and iron work, boat-building, fuel-cutting, truckage, etc., cause a large amount of money to circulate among our fishing population and fair wages to be paid to thousands of hands—men, women and children. Great Britain is our best market for preserved lobsters. We also export annually some 3,000,000 cans to the United States. France takes about 200,000 cans, and the remainder is divided between the West Indies, Germany, Brazil, and some other markets of South America.

A word about the oyster fishery naturally finds its place here. This mollusk, so well known by epicures of all countries, is still comparatively abundant in Canada. In Europe, owing to its scarcity, it sells at a fabulous price, and wealthy people alone can indulge in this luxury; but on our coasts almost everybody can, from time to time, enjoy a good oyster soup. We have the Malpeque, the St. Simon, the Caraquet, and many other varieties, deriving their names from the localities where the banks from which they are taken are situated. Oyster fishing is carried on chiefly on the coasts of Prince Edward Island and New Brunswick, and yields annually about $260,000.

Fresh-water fisheries.—The inland waters of Canada teem with salmon, whitefish, salmon trout, pickerel, bass, speckled trout, ouinaniche, sturgeon, muskellunge, etc. In 1892 the salmon fishery yielded $2,500,000. Of all the provinces of the Dominion, British Columbia is the most celebrated for its salmon fishery, and within the last few years this industry has attained there almost colossal proportions. Whitefish and trout fisheries are carried out on a large scale, chiefly on the great lakes of Ontario, which are all well known to you. The most valuable is the whitefish, the catch of which amounted to 24,000,000 pounds last year, valued at $1,500,000.

The salmon rivers of Quebec and New Brunswick are justly famous, as every lover of the gentle art in the United States well knows. The salmon pools of the Restigouche, of the Metapedia, of the Cescapedia, of the Miramichi, of the Grand River, of the Nisissiguit, of all the rivers of the north and south shores of the St. Lawrence, are celebrated throughout the whole world and are every year increasing in value. Only a few days ago the salmon-angling privilege of the Grand Cascapedia River was let for $6,125 per year to an American syndicate. Who has not heard of the sport of ouinaniche fishing in the St. John Valley, near Quebec? Almost innumerable in that neighborhood are the lakes and rivers where you will find all kinds of good game fish. Wealthy gentlemen from Europe and America are coming by hundreds every season to enjoy the fly fishing in our lakes and rivers, and thus is established this reciprocity of which we have heard so much lately—we give them amusements and pleasure, and they give us money.

Protected by judicious laws which are strictly enforced, and assisted by a large force of fishery officers and armed cruisers, there is no danger of our supply of fish being exhausted by overfishing or by the prevalence of injurious practices. To still further aid natural reproduction, fourteen hatcheries are in operation in the several provinces of the Dominion. From these, fully 140,000,000 fry of young fish, chiefly salmon, whitefish, salmon trout, and lobsters, were planted in 1892.

Canada is one of the rare countries where fish-breeding is carried on under the direct control of the government, and if our hatcheries have not yet produced all the practical results which they were expected to give, they have proved, however, that, carried on judiciously, they can help in a good measure to replenish some of our lakes and rivers where indiscriminate fishing has been indulged in rather extensively.

The advantage of the fishery intelligence bureaus, inaugurated in Canada on a modest scale in 1889, became so apparent that there are now 55 reporting stations distributed all along the Atlantic coast from New Brunswick to the Magdalen Islands, and the coasts of Labrador and the Gulf of St. Lawrence. The object is to keep masters of fishing vessels advised of the movements of the fish. The compilation of these reports will, in a few years, enable our government to put up charts on which the migrations of the different kinds of commercial fish will be easily followed.

The pursuit of an industry such as that of fishing within 900 miies of the coast is necessarily attended with many dangers and peculiar drawbacks. Exposure of life and property is frequent. Success depends very much on the seasons. Many kinds of fish of erratic habits are eccentric in their movements. Plenty and scarcity may alternate in places, from which the settlers depending wholly on any fishery have to escape. Within 20 miles of a settlement, on a barren and uninhabited coast, the fish may strike and remain without any possibility of their whereabouts being known; at other places they may be abundant beyond the capacity of shoremen and vessels to catch them, and yet fisherman not far distant may be unable to procure even a sufficient quantity for their winter's supply. Vessels may return empty in one season from fishing-grounds where previously or afterwards the fish abound. Some may lose the greater and best part of each season in searching after the shoals. Still the waters teem with fish, and sooner or later they approach the shore or frequent the shallows.

The fishery intelligence bureaus have in some measure provided against these vicissitudes. They have proved of material assistance to the fishermen, and aided considerably in developing the fisheries in our country. Besides affording greater inducement and security to employers of capital and inspiring confidence to those exposed to danger and hardships, they will undoubtedly enable us to increase production and enlarge our exports.

Canada was glad of the opportunity offered by the management of the World's Columbian Exposition to show the extent and the richness of its fisheries; and it has made there one of the largest, most complete, and best displays in the Fisheries Building, and in its competition with the rest of the world its exhibit has come out with flying colors, as may be ascertained by the number of awards it has received.

38.—THE FISHING INDUSTRY OF LAKE ERIE, PAST AND PRESENT.

BY C. M. KEYES.

The subject suggested by the president of our State fish commission as the topic of this paper is one of wide range and too extensive in scope to be thoroughly discussed in the time which I may occupy in courtesy to the gentlemen of this convention, all of whom will doubtless have subjects and matters of great importance to the fishing industry to bring up for consideration. I shall therefore be as concise as the subject will allow, and not trench on your valuable time more than is absolutely necessary.

The early fishing in the waters of Lake Erie was crude in character and limited in operation. Up to the year 1850 fishing was mainly confined to the waters of the bays, inlets, and rivers tributary to the lake, with some feeble efforts at gill-net fishing by small row or sail boats operating near the islands, reefs, and along the shore of the lake. There is no authenticated record that prior to that time any steam craft was used in connection with the fisheries of the lake, nor, in fact, until some years after that period.

Fishing, as an industry of any considerable importance in Lake Erie, may fairly be dated from the year 1850, although it did not attain to any great magnitude until some years after that.

Pound-net fishing commenced about that time, and from the very start gave new impetus to the business; this was in consequence of the fact that the fish product became at once much larger, was produced in a more merchantable condition, and continued over a larger period of time each year, thus enabling the dealer to send his fish with greater regularity and in much better condition to the markets of the country. By reason also of being able to furnish the inland dealer with a constant and certain supply of fresh fish, wholesale dealers in all the large cities established themselves, thus becoming distributing-points for the fish food of the waters of Lake Erie and enabling the consumers living at distant points to obtain a valuable addition to their food supply and in a wholesome condition.

The growth of the industry from the period above mentioned was steady and certain. Each year witnessed new and improved methods in catching, preserving, and marketing the fish. In the early years, in fact until the year 1867, all the fish brought to the local markets for handling, in amounts exceeding the requirements for immediate shipments, had to be salted, thus getting to the consumer in a very inferior condition as a food product. About this time the system of freezing fresh fish and storing them in refrigerating rooms for winter consumption was put in practice at

Sandusky, Ohio, by West & Smith, and in a few years the system became general and many hundred tons of fish formerly lost to the trade were marketed fresh during the winter months, when fishing becomes impossible or impracticable.

I am dealing with this question from a commercial standpoint, because from no other has the subject material interest to any very considerable portion of our people. The fishing industry is of vital interest to the citizen generally for two reasons only: It furnishes a source of employment for a large amount of labor and capital, and it produces a large and valuable food product, at low prices to the general public. through the channels of trade the outgrowth of this great industry.

From the statistics furnished by the U. S. Fish Commission we find that 178,41 persons are annually employed in fishing and fisheries in this country, with a capital investment of $55,699,278, indicating that nearly one-sixtieth of our population are engaged or directly interested in this business as a means of livelihood. It is no wonder, then, that this subject is attracting such widespread interest among the best thinkers of our land, and that State and National Governments are giving to it the serious and watchful attention its importance so clearly merits.

Until recent years the fish supply of Lake Erie was so great that the question of its becoming exhausted was thought of only as a possibility, and but little was done looking towards maintaining the supply. The whitefish that once swarmed in its waters in vast numbers, being most sought for by reason of their greater value, was the first of the fishes to show material decrease; the pike, the pickerel, and the bass also gradually decreased, while other fishes, such as the herring and blue pike seemed to increase, probably owing to the fact that they were very little sought for because of the low price paid fishermen for them.

About 1869 the first herring were frozen for winter trade. Twenty tons of these fish were frozen that year by Ferdinand Geisdorf, of Sandusky, Ohio, and marketed in Pittsburg, Pa., where they met with such favor by the trade that all the firms operating in fish in Sandusky froze quite a quantity of herring the following season; so from the year 1870 may fairly be dated the time when herring became one of the principal, if not the principal, fish of commerce from the fisheries of Lake Erie. Hitherto it had been classed among the cheap and undesirable fish taken by our fishermen, and the greater part of the catch saved to the trade was marketed as a salted product. The herring rapidly advanced in favor, and the fishermen turned their attention more particularly to its capture. Hitherto it had only been taken in pound nets, almost the exclusive method of fishing used in the western half of Lake Erie from 1850 to 1888, a period of thirty-eight years.

Fishing with gill net was confined to the large-mesh nets used in catching whitefish and trout, as herring was too cheap a fish to pay gill-net fishermen to catch, and such nets were mainly operated in the deep water of the east end of the lake. They continued to operate these large-mesh gill nets until the whitefish and trout were practically destroyed. In the meantime the herring, blue pike, and sauger actually increased in numbers in the waters of the lake. Notwithstanding pound-net fishing kept increasing from year to year, these fish continued to increase until the gill-net fishermen commenced fishing their small-mesh nets in the western part of Lake Erie, at a time when these fish are on the road to their spawning-grounds, which mainly lie in the western part of the lake.

To prove this statement we beg to refer you to statements taken from the books of eight of the leading fish-dealers of Ohio, doing business in the cities of Huron, Sandusky, and Toledo, showing the yearly catch since 1888, since which time only has gill-net fishing, in the part of the lake referred to, been carried on as business of any magnitude. The following exhibit shows the actual catch of the different varieties of fish by these eight firms, figured in pounds from 1888 to 1892, inclusive:

Years.	White-fish.	Wall-eyed pike.	Sauger.	Catfish.	Herring.	Perch.
1888	834, 951	608, 514	2, 037, 655	218, 446	10, 801, 802	507, 098
1889	526, 366	555, 700	1, 784, 134	138, 732	10, 272, 945	401, 210
1890	313, 753	535, 800	1, 439, 380	87, 965	9, 638, 795	656, 365
1891	360, 980	523, 500	1, 962, 000	99, 535	7, 280, 792	1, 027, 110
1892	320, 202	349, 148	2, 203, 627	39, 780	1, 900, 868	775, 790

This shows that while the annual catch varied some and steadily lessened in amount, there was no startling decrease until the year 1892, and it was then more especially noticeable in the herring catch, which was over 7,000,000 pounds in 1891 and less than 2,000,000 pounds in 1892.

The western half of Lake Erie has always been considered the great fishing-ground of the lake, made so by reason of that portion of the lake being the natural spawning-ground for the fishes it contains and for the abundance of fish food found in its waters. More of the species spawn in the spring than in the fall season—in fact, it may be said that the entire period from March 1 to the middle of June is covered by some one of the species as a spawning season, and while it is clearly impracticable to stop the catching of fish at such times, still the fisherman could be easily required to so operate their nets as not to prevent the fish from reaching their spawning-grounds. In the fall the fish again visit this locality in large numbers, some varieties for the purpose of depositing their eggs, while others, no doubt, come because the shoal waters of the western portion of the lake cool quicker, and to feed off the eggs of the spawning fish as well as the natural food so abundantly found on the reefs and shoals.

This statement of facts clearly shows that the fishes of Lake Erie make regular pilgrimages to the western half of the lake in the spring and fall season, and that nearly all the varieties of fish inhabiting its waters are found there in quantities during both of these periods.

To make a close-season at either of these times would prevent the fishermen taking those fish that are not spawning, as well as those that are, which would not only be unjust to the fishermen, but injurious to the trade, which demands a steady and constant supply. In fact, to make the spawning season of the different fishes a closed season would practically put a stop to fishing in the western half of Lake Erie at the time when the fish are produced in their best condition to the trade, and when, by reason of more favorable conditions for shipping, the consumer gets the fish in much finer condition than is possible in the summer months, the time when none of the fishes spawn.

There are two principal systems of fishing operated by commercial fishermen in these waters—the pound net or stationery net, and the gill net or movable net.

The pound net is composed of three separate parts—the leader, the heart, and crib or pound. The leader is from 50 to 60 rods in length, the heart from 6 to 8 rods in length, and the crib from 28 to 30 feet square. The mesh of pound nets, as now used, is from 5 to 7 inches for all parts of the net except the crib, which is the part daily raised. All except the very largest fish can go through the leaders and hearts at will, and undoubtedly do so, and can swim under the crib of every pound on Lake Erie, thus preventing no fish, except the very largest, from passing through.

Of course, those fish that follow the leader, which is from 50 to 60 rods long, and then into the hearts and finally get into the crib, are probably nearly all saved to the fisherman. But what practical pound-net fisherman will say what proportion of the fish, after striking a leader to a pound net, will make the journey along the leader and then through the heart, and finally swim through the tunnel into the crib, and what proportion will go through this large-mesh leader and finally escape altogether.

Thus it is that while pound nets present something of an obstacle to the onward progress of the fish seeking a proper place to deposit their spawn, they do not present an absolute bar to their progress, by reason of the large-sized mesh used as above indicated; while gill nets, being a small-mesh net, set in long lines along the bottom of the lake, present an absolute wall to the further progress of the fish, thus diverting them from their natural course, and, in fishing parlance, breaking up and destroying the schools.

Then, again, pound nets can only be set near the shore, and being stationary nets fastened to piles, can only catch the fish that come to them, while gill nets are set here to-day and there to-morrow, and always in such manner as to head off and obstruct the onward progress of the fish. Pound nets can, at best, obstruct an eighth or tenth of the lake, leaving the balance of the lake a free passage, while gill nets, in these late years, are operated in an almost unbroken line from shore to shore, and were so operated last season. Beginning at a point near Vermillion, Ohio, these lines of gill nets extended into Canadian waters, thus shutting the schools of herring off from the island region and the head of the lake, where the spawning-grounds mostly lie. This was fully demonstrated by the very small catch of herring last season in the western half of the lake.

It is evident to men operating the fisheries that unless these fish are permitted to reach the spawning-grounds, which lie all over the western portion of the lake, they must of necessity rapidly decrease in the waters of Lake Erie, and as a practical fisherman I see only one remedy, and that is to limit the fishing of nets in such manner as to leave a passageway for the fish to their accustomed spawning-grounds, and the only practical way to do this is to prohibit the fishing of any nets at a greater distance than, say, 4 miles from shore where the lake is 30 miles in width or more; and in all passageways where the distance across is 10 miles or less, nets be permitted to fish at a distance from either shore not more than one-fourth of the distance across, and that all nets be set at right angles to the shore. This would leave a wide waterway for the fish, unobstructed by nets of any kind, and thus permit their free passage to the spawning-grounds, which lie all over the western part of the lake.

The better-informed and unprejudiced fishermen are all agreed that if nets are so operated as to permit the fishes to reach their natural spawning-grounds, no system of fishing will ever reduce the supply below the present standard, and not only that, but that the fishes would soon show an increase. It may not be practical or right to say, by law, that this or that system of fishing shall prevail, but it is both practical and right to say that nets shall be so operated that the fish may, with a reasonable certainty, reach their natural spawning-grounds, and so reproduce their kind in the natural way. I believe that the State and Government fish hatcheries are doing a good work in stocking the waters of our lakes and rivers; but the natural way is surely the better way, and any practical law looking to that end should certainly have the hearty support of all who are interested in this industry.

The States undoubtedly have certain control over our inland waters, and are in the main endeavoring to properly regulate by law the fishing and fisheries, but by reason of the great diversity of interests of the different States in connection with this industry it is the opinion of many of our best thinkers that the General Government may yet be asked to assume more control of the inland fisheries than has hitherto been considered advisable or within the scope of its powers. The fisheries of our inland waters furnish the people with a very valuable article of food, and any legislation on this subject should consider the rights and necessities of the consumer as well as the producer. The consumer has the right to be protected by law in this, that the fish shall be taken in such a manner as to warrant their being marketed in a wholesome condition. Inspectors or wardens should be appointed, with full powers to condemn all fish offered in our markets that are unfit for food, made so by the manner or season in which they are caught, or for any other cause which may be properly remedied by law. It is estimated that 8,000 tons of herring were taken from the waters of Lake Erie during the months of June, July, and August, and of that part of this product marketed in a fresh condition during this hot period undoubtedly a very considerable proportion reached the consumer in a stale or unwholesome condition, and very much of it was utterly wasted.

The State of Ohio has a closed season from June 15 to September 10, but Pennsylvania has not, and so the great slaughter and waste of herring goes on during the summer months, when this fish is of the least value as a food product, and by reason of the hot weather can only be sent in limited quantities fresh to the consumer, and then only to cities that have large markets, supplied with refrigerators for keeping them. Large quantities of young or half-grown whitefish are also taken in the summer months by gill-net fisherman, operating their nets in the deep waters of the eastern end of the lake, and are thrown away or sold as herring. The fish product of the great lakes has become such an important article of food to the vast population tributary thereto that laws prohibiting unreasonable waste or destruction of this valuable commodity of commerce should be enacted and enforced. The people generally look to commercial fisherman only for their supply of fish food, and, in a way, are as much interested in making commercial fishing a successful industry as are the men operating the fisheries.

Our law-making bodies, then, should pass laws that will not only foster and increase this great industry, but will also compel dealers and shippers to produce and send to the consumer, wherever he may be located, this valuable food product in the most perfect and wholesome condition possible. The people have a right to this protection and should enforce their just demands through the medium of their respective legislators. This industry should not be hampered by laws based on the fanciful theories of the fish-culturist or influenced by the arguments of the fish vandals who operate on the plan that all are fish that come to their nets; but the best interests of the whole public should be considered, and in the end such a system of laws would be to the best interests of the producer and the consumer alike.

39.—THE FISHERIES OF THE VIRGINIA COAST.

BY J. T. WILKINS, JR., M. D.,
Fish Commissioner of Virginia.

Regarding the fisheries of the Chesapeake Bay and the Atlantic coast of Virginia, the question of greatest importance to our fishermen is the appalling decline in the number of the free migratory fishes that annually visit the waters of our State. Years ago, as late even as 1860, with the simplest contrivances for their capture, it was impossible to utilize all the fish caught. The markets of Baltimore, Norfolk, and Richmond were abundantly supplied by the fishermen of these respective localities. The only devices for the capture of fish up to that time and for several years after were the haul seine and gill net. With the advent of railroads and the employment of ice, more distant markets were reached, with the consequent demand for a larger supply of fish. To meet this growing demand the fish pound was ingeniously devised, and for several years thereafter but little effect upon the apparently inexhaustible resources of the sea was to be observed, notwithstanding the fact that the pound nets, weirs, etc., multiplied with marvelous rapidity.

There were 162 fish pounds in the Chesapeake Bay and its tributaries in 1880, 412 in 1883, and 550 in 1888. In 1880 the estimated value of fish caught was $906,068; in 1883, $1,258,576; in 1888, $1,265,000; in 1893 (estimated), $725,000, three-fourths of which were shad. In 1885 the tide of an abundant catch reached its highest flood, since which time, fluctuating year by year, the fortunes of the fishermen have rapidly ebbed away, until to-day, in a large majority of cases, it is a losing venture to engage in this industry. Our fishermen are finding their occupation gone, an occupation that gave employment to 25,000 people and added largely to the taxable values of the State.

Is the fish pound responsible for this sad condition of affairs? There is such close connection between the introduction and multiplication of this all-devouring fish pound and the continually decreasing run of our pelagic fishes as to be at least suggestive. Nothing in the shape of a fish that ever enters it comes forth again alive. Large and small, old and young, the barren and the gravid fish—all are sacrificed to the blind cupidity of their pursuers.

If we assume that the pound-net fishing continuing from the middle of February to the first of October, and which it is almost a physical impossibility for fish to escape, running the gauntlet from the mouth of the Chesapeake Bay to the fresh waters of all its great rivers—if we assume that this is to be charged with the dire condition of our fisheries, what steps can we recommend as an abatement to this standing menace to the sad remnant of a once grand industry? Many of our people would be thrown out of employment and much capital now invested in the pound nets would be sacrificed if the pound nets were to be abolished. Nor could one State alone repair the damage, already too long continued, without the hearty coöperation by legislation of all the Atlantic States—concurrent legislation. The efforts of the fish-culturists will be barren of good results without this heroic treatment as supplementary to artificial propagation, and a close period during their spawning season and perfect freedom to reach their natural spawning grounds.

It is to the serious consideration of this matter that I would call the attention of gentlemen here to-day.

40.—NOTES ON THE IRISH MACKEREL FISHERIES.

BY REV. WILLIAM SPOTSWOOD GREEN,

Inspector of Irish Fisheries.

The great herring pond, as the Atlantic is often called, is not only a means of facilitating the communication of men living in countries 2,000 miles apart, but it also affords the means by which certain fish can wander from the shores of one country to the other.

The mackerel (*Scomber scombrus*), owing to the similarity of the species on both sides of the Atlantic, seems to point to intercommunication.

In the following notes which, owing to the press of other duties, have been commenced only forty-eight hours before the date for posting, I shall allude to one of our great Atlantic fisheries, and this I am able to attempt, owing to the knowledge I have gained of the American fisheries from the valuable publications of the U. S. Commission of Fish and Fisheries, and from my interesting but too brief visit to the hospitable roof at Woods Holl in Massachusetts.

The spring mackerel fishery.—This, the most valuable of the Irish sea fisheries, commences on the west coast of Ireland in the end of March or the early part of April. On the 6th of April in this year (1893) and on the 4th of April last year the first large takes were made. Owing to the observations made on the American coast as to temperature, I was led to make similar observations here, and I found that the night on which the open-sea temperature reached 50° was the night on which the large schools appeared. The fish were taken by boats near shore and for over 20 miles to sea. All along the coast the boats had shot their nets with little or no result for over a week previous to the date named. In 1892 I shot a train of mackerel nets 10 miles outside the Arran Islands off Galway Bay on the 11th of March, and again on several following nights when the sea temperature was 46° and air temperature 37°, with frequent snow showers. On each night we captured two or three mackerel and a few herrings. The mackerel were of small size, about 13 to 14 inches long. They were of both sexes and about half ripe. This went on until April 6; then the sea temperature rose to 50°, and large mackerel, 19 inches long and between 2 and 3 pounds in weight, were immediately captured in thousands all along the coast. There seems, therefore to be a few mackerel always to be caught, possibly wanderers from the great body. How far mackerel may thus be scattered all over the North Atlantic and the abundance of the supply are as yet unknown.

Another fact to be considered is that though mackerel are not captured in the open sea in any large quantities until the sea temperature reaches 50°, still the canoes and row boats which can shoot their nets close to shore and in certain bays get the large

spring fish usually two or three weeks earlier than boats
sea may be from 40 to 80 fathoms deep. And this is the
still low. This seemingly points to the conclusion that m
shore keep deep down, not necessarily at the bottom; tha
they are forced upward along the coast line, but that
the upper waters to spawn until there is a suitable surf
June they shed their ova, and during these months th
of various sizes.

The ordinary gill nets for mackerel are fished at t
bays the fishermen sink a portion of the net and mo
spring, on the north coast of Mayo, the fishermen slin
manner of herring nets, and often find mackerel in gre
are slung several fathoms from the surface.

When spawning is over, the fish scatter and the sp
While the schools are on the coast they often wander t
no evidence to show that in approaching the coast the
north or south. From Cork to Donegal, which are th
on the Irish coast, they appear at the same time. Loc
about a good deal and come to certain localities in g
than in others.

In America the mackerel fleet proceeds southward
meet the schools of fish which apparently migrate fro
Cape Hatteras is about 35° N. latitude and the coast
the same isotherm reaches the two places about same d
spring mackerel fishery open simultaneously.

Statistics show that on the American coast fishin
passu with the isotherm of 50°.

On our side of the Atlantic we have no great st
that from Cape Hatteras to Nova Scotia, but that no s
be inferred from the fact that large numbers of Frenc
to commence the spring fishery and there find the ea
Cornish mackerel fishery is the southern extension o
earlier and the general run of fish are smaller.

The value of this fishery to the country may be e
value of the fish to the fishermen for the twelve week
the Irish coast was £150,000. The amount spent on i
was of course in proportion.

Method of capture.—The only method employed i
is by gill nets; the larger boats use trains of nets al
them. The row boats and canvas canoes, by which
either anchor their nets or drift with them. The spr
tured by hook and line, and the fishermen have com
blind.

The autumn mackerel fishery.—This fishery receiv
owing to the failure of the mackerel fishery on th
looked for from Ireland. Since then this fishery h

country. America could confer no greater boon upon Ireland than in reducing the tariff on Irish-cured mackerel.

The autumn schools begin to appear on the coast about the end of July, and are soon to be met with all around the British islands and in the North Sea as far as Norway. They are at first of small size; some of the schools, which as a rule make their way up into the large bays and creeks, being little larger than sprats. Those about a foot long are taken in great numbers on hook and line. The size of the fish gradually improves, and mackerel up to 2 pounds weight and 18 inches long may be met with in August. The small fish are still met with. All that I have examined were sexually immature. It is possible that the larger fish are those which spawned in the spring, but I have failed to find any remains in the ovaries.

As September advances the fish cease to accept bait, and net fishing is once more universal. Seines are largely used, the American purse seine having become common. Gill nets are also used. The season lasts much longer than the spring fishing. In some cases it has gone on right through the winter; and this, combined with the facts that it is carried on chiefly by local fishermen, and not by all the strangers who congregate in the spring season, renders it a greater benefit to the country. The fresh-mackerel business necessitates concentration to insure ice and transport, while the pickled-mackerel trade, which is chiefly the autumn fishery, is not so limited and consequently is prosecuted far and wide along the coast.

It is evident that these two fisheries are a severe strain on the supply, and the questions naturally arise, How long can they last? and, Ought restrictions be placed on them? The one is a killing of spawning fish, but is, however, the most important herring fishery; the other is the killing of fish sexually immature. The one is valuable owing to the very high prices which are to be obtained in the spring; the other, though prices are not more than one-quarter as good, is valuable from its wide distribution on the coast and the length of the season when it can be prosecuted. In America, where the mackerel fishing has been prosecuted for over 200 years, we find enactments as early as 1670 prohibiting the capture of spring mackerel on account of being spawning fish. In a few years later the law was repealed. In Ireland the great development of the spring mackerel fishery dates back to only 30 years ago, and the autumn fishing to 1887. Prior to those dates the fishery was so insignificant as not to be worth mentioning in the old fishery reports. The questions which were discussed on the American coast centuries ago are before us now. For the answer fuller knowledge is necessary, both as to the life-history of the fish and the distribution of the species. It is the one problem, and can be tackled on both sides of the wide Atlantic.

There are a few points of difference to be noted between the American and Irish fisheries. In the American spring fishery the mackerel school on the surface and can be seen and taken by seines. With us this is not the case until the autumn; very often the best nights for fishing are when there is no sign whatever of the fish. In the American spring fishery the fishing hook and line has been largely used. With us the mackerel can not be caught with bait until summer. Baiting the water, so common in America, has not been found of much use on the Irish coast. In America the spring and autumn fishing are continuous. On the Irish coast there is a distinct blank time between the two fishings.

The boats employed.—Instead of the 80-ton schooners of the American coast, with their two seine boats, and along shore the dories, the Irish fishing is prosecuted—

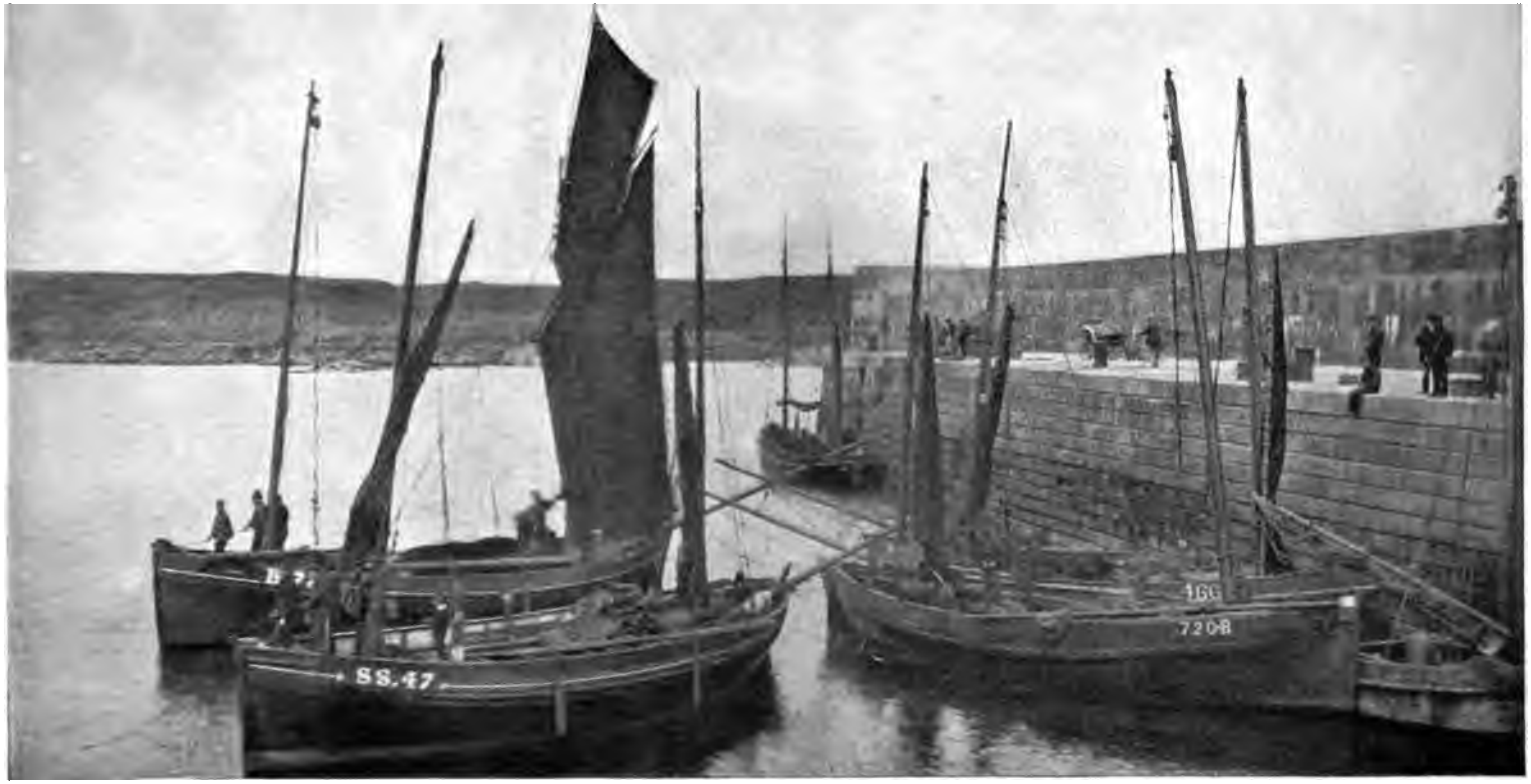
(1) By 30-ton boats which can lower their masts when the nets are shot, and are in many cases provided with steam gear for hauling the nets.

(2) By rowboats and by canvas canoes which take three to six nets to the fishing-ground. In some bays in the west of Ireland from 60 to 100 of these canoes take part in the fishing. They are particularly seaworthy, and, owing to their great lightness, can easily be removed from the beaches when heavy seas break upon the coast. They differ in construction on various parts of the coast; those on the Kerry coast are the most carefully built, while the most primitive design is met with in Donegal.

The sheer of the floor, coming right out of the water both fore and aft, gives them the best qualities of the dory, and the delicate framework enables them to adopt more graceful lines than is possible in the American craft.

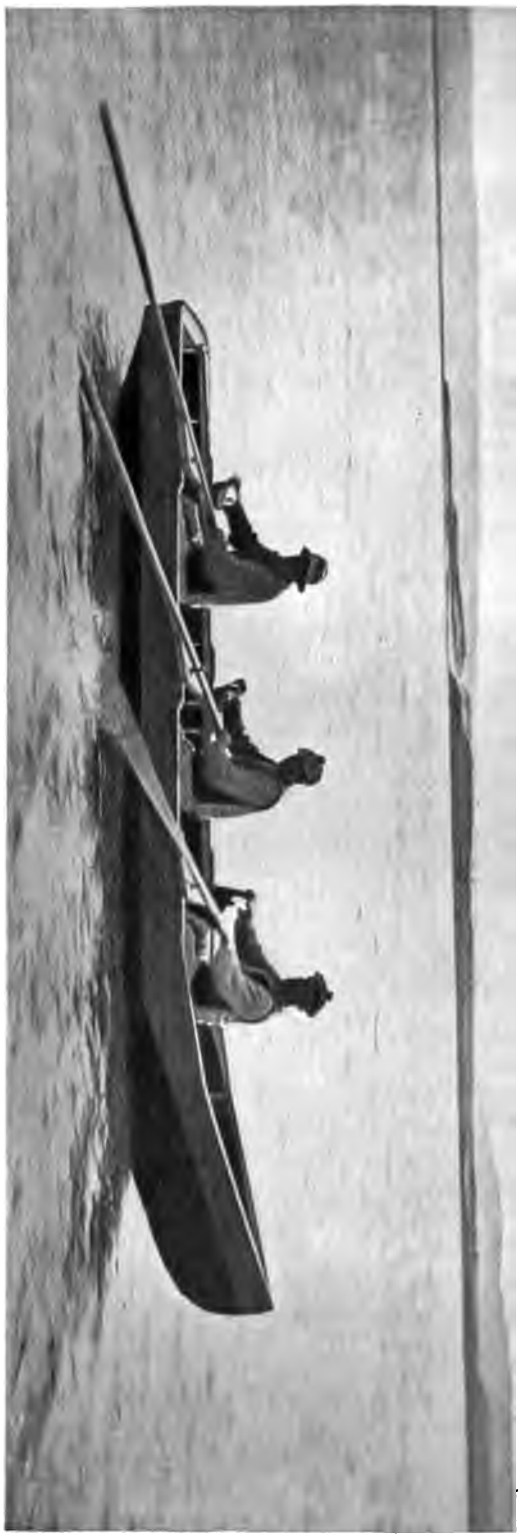
During the spring of the present year 662 large boats (including 93 from France) fished mackerel on the Irish coast, and 809 row boats and canoes.

Annexed are four photographs taken by Mr. R. Welch, of Belfast, who has made a large series of such views.

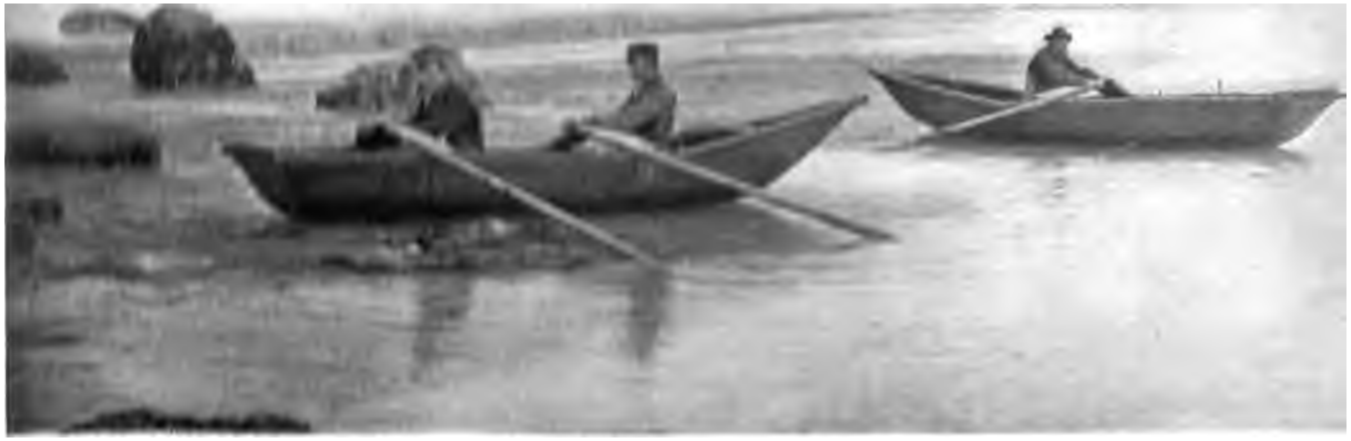


ARDGLASS HERRING FISHERY. "HAULING OUT." THE LARGER CLASS OF MACKEREL BOATS

PLATE 14



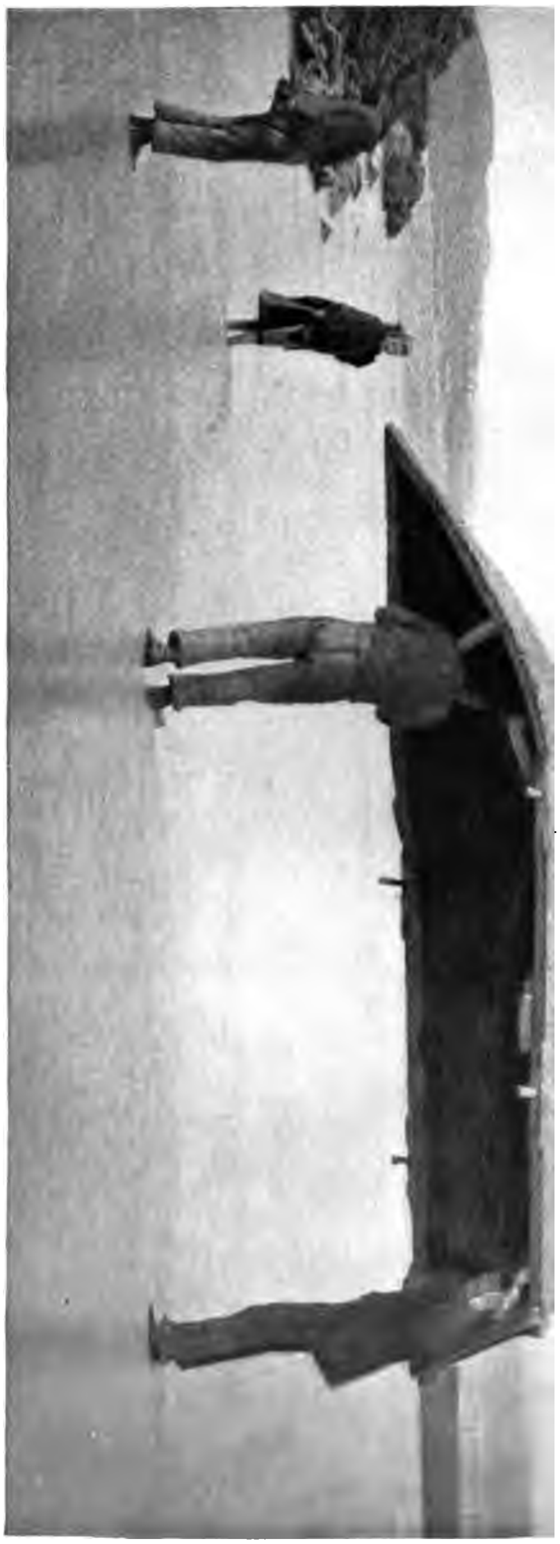
SOUTH ISLES OF ARAN ISLANDERS ROWING A CANVAS CURRACH.



DONEGAL CANVAS CURRACHS, ROSAPENNA

BRYANT WALKER LIBRARY
MUSEUM OF ZOOLOGY
UNIVERSITY OF MICHIGAN

PLATE 16.



CARRYING A DONEGAL CURRACH

41.—PAST AND FUTURE OF THE FUR SEAL.

BY JOSEPH STANLEY-BROWN.

There are but two groups of fur seals to furnish to the world its supply of seal skins, the fur seal of the north and the fur seal of the south.

When Sir Francis Drake circumnavigated the globe in 1577–80 the *Arctocephalus*, or southern fur seal, was to be found at not less than thirty localities, and their numbers aggegated millions. To-day the contributions of these southern waters are from three resorts, and do not usually reach 15,000 skins annually.

When Vitus Bering, in 1741, was wrecked upon the Commander Islands, off the coast of Kamchatka, and Pribilof searched out, in 1786–87, the group of islands in Bering Sea that bears his name, there were discovered, not only the chief breeding-grounds of the northern fur seal, *Callorhinus ursinus*, but some of the most superb seal rookeries the world has ever known. It is questionable if mortal vision ever rested upon more magnificent displays of amphibian life than were to be seen on the island of St. Paul at the time of its discovery. To-day these subarctic resorts are prostrate; their glory also has departed, and they furnish a home for but a mere remnant of the seals that formerly swarmed in myriads along their rocky shores.

For two years the hopes of thoughtful persons were high, that through the medium of international negotiations and the deliberations of wise and able men the safety of the fur seal would be at last secured. To-day, when the decision of the Paris tribunal is common property, we find public opinion divided on the question as to whether the practical application of the decision will preserve the fur seal as a commercial commodity.

Characteristics of the seal.—The condition of affairs thus briefly outlined is all the more deplorable when we consider the characteristics of the animal with which we are dealing. It is a creature peculiarly adapted by its habits to man's management. It occupies no territory needed, as were the buffalo's feeding-grounds, for the subsistence of more valuable domestic animals; no herders are required to prevent its being lost in the wastes of the ocean, and no expense is incurred either to protect it from the inclemency of the weather or to provide a winter food supply; yet with more certainty than the ranchman's flocks and herds seek the home range do the seals annually return to their breeding-grounds where, under proper management, they can without injury to the parent stock be made to yield a profit equal to if not greater than that derived from the cattle of the plains or the sheep of the mountains.

The southern fur seal and its destruction.—Despite these characteristics, which must have been apparent to the most ignorant and unobservant, what has been the course of events? Turning first to the fur seal of the south we find that as early as C90 some little interest was manifested in its capture, but it was not until the close of the last century that the pursuit was begun in earnest. Hardy mariners, stimulated by the hope of sharing in the profits of the fur trade which the Russians had developed with the Chinese, searched out the resorts of the southern fur seal; ravaged them year after year, in season and out of season; slaughtered the helpless creatures with clubs on land regardless of age or sex; gathered a harvest of sixteen or seventeen million skins, and by 1830 had practically destroyed, in the southern seas, this valuable fur-bearing animal. If all these resorts were in their original condition and under wise and prudent direction, they could easily supply to the fur trade annually something like half a million skins, with corresponding advantage to an army of skilled artisans. As it is, indiscriminate butchery has left only the Lobos Islands rookeries at the mouth of the La Plata River and a few insignificant resorts at Cape Horn and the Cape of Good Hope, the total yearly yield of which is, as before stated, less than 15,000 skins. Such destruction is left absolutely without justification in the face of man's entire ability to maintain the fur-seal rookeries at the highest possible limits permitted by the operation of nature's restrictions, or when depleted to develop them again. This is not idle speculation, but rests upon a firm foundation of fact furnished by the history of the fur seal of the north.

The northern fur seal and its relation to the sealskin industry.—The two great resorts of the northern fur seal are the Pribilof and Commander islands in Bering Sea. Robbens Reef, a rocky islet in the Okhotsk Sea, has a small rookery, and a few localities of minor importance are found along the Kurile Islands. While the Russians who first discovered these resorts prohibited all interference from outsiders, their own treatment of the seals was similar to that practiced by the sailors in the south. No attention was paid to sex, season, or period of procreation, and it was not long before the end came there just as it had done in the south. The Russians were taught by this severe lesson that the only way in which the rookeries could be restored and perpetuated was to protect the females from death and the breeding-grounds from molestation. This course, accompanied by practically a suspension of killing during certain years, was rigidly adhered to with the result that when the rookeries of the Pribilof Islands were turned over to the United States in 1867 their condition, instead of being one of exhaustion, approximated that which existed when they were first discovered. The truth of this will be more apparent when it is stated that in 1868, before the United States could assume and exercise control over its newly acquired possessions, nearly a quarter of a million skins were improperly taken from the islands of St. Paul and St. George by unauthorized persons without apparently producing any diminution of the numbers which came the following year.

Although there are but four of these northern localities, and Russian mismanagement from time to time played such havoc with them that the catch was an uncertain quantity, still they have contributed since their discovery between 5,000,000 and 6,000,000 skins to the fur trade, or about one-third as many as have been furnished by the southern resorts. From the time that the fur seal of the south ceased to be of commercial importance trade has relied upon these rookeries. Thanks to the more enlightened policy employed by the Russians, and adopted and improved upon by the United States, these rookeries of Bering Sea contributed to commerce for the twenty years ending with 1889 a uniform yearly quota of nearly 150,000 pelts, which formed the basis of and made possible the systematized sealskin business of modern times. As a raw commodity they sold for an average of $2,500,000 at the annual London trade sales, and the Pribilof quota yielded the Government of the United States in revenue more than the $7,200,000 originally paid for the entire Territory of Alaska. The value of raw sealskins is now represented by about $15 for skins taken at sea and $30 for Pribilof skins. At the present revenue rate, if it were now possible to take from the Pribilof Islands the former yearly quota, the Government income would be nearly $1,000,000 annually.

Importance of the sealskin industry.—The sealskin industry is of no slight importance and its proportions are but roughly indicated by the first profit on the raw skins. These peltries must be gathered in remote regions; they form part of the transportation business of railroad and steamship lines; coopers must make casks for their shipment; they must pass through the hands of many laborers before they reach the 40 buyers in London who purchase them, and the 2,000 skilled artisans who convert them into fabrics suited to the use of trade; and when all this is done there must still be stores maintained and clerks employed in order that they may find their way to the wealthy consumers. The labor incident to the taking, transporting, manipulating, and disposing of these peltries demands the employment of thousands of persons each year, and when we recall the prices paid for these skins when converted into the garments dictated by fashion, it will readily be seen that it is an industry the ultimate value of which is represented by millions of dollars annually. Above all it is a peculiarly worthy industry, in that it gives occupation to many, while the profits come from the purses of those best able to pay them.

Cause of the destruction of the northern fur seal.—Some ten years ago there was put in operation on the American side of the Pacific ocean an agency of destruction, the growth of which, if uninterrupted, promised to prove as effective as did the sailors' clubs upon the southern resorts. Its promise has been generously kept, and from its deadly though partially controlled effects the rookeries are now suffering. That agency was pelagic sealing, or the taking of seals at sea by means of weapons. The source of the injury is the indiscriminate killing. Whether this is practiced on land, as in the south, or at sea, as in the north, the outcome is the same. No animal which produces but a single offspring each year can long survive an attack which involves the death of the producing class, the females. I am aware that there is another side to this question, and that two great nations point each a finger at the other and say: "You did it." The subject-matter of that contention is only germane to such a paper as this in so far as it touches upon the career of the seal, and only to that extent will it be referred to.

England and Canada hold the theory (which, in justice to them, should be stated) that the decline of the northern rookeries was due to excessive killing on the islands, pelagic sealing being a factor of only secondary importance. If this theory meant that after pelagic sealing had made serious inroads upon the seal herds it was excessive killing to continue taking the annual quota of 100,000 skins, it would be a sound one, and the United States would be culpable to that extent, but England and Canada would not accept this limitation; they want it to account for much more. They fail, however, to sustain their theory until they show by clearest proof that the decline of the rookeries began prior to the development of pelagic sealing, and also get rid of the awkward fact that for the first twelve or fifteen years there was no difficulty in securing the annual quota allowed by law. Why did this alleged decadence through excessive killing on land take so long to manifest itself? Certainly the evils of indiscrimination is not inherent in land killing; on the contrary, selection can be exercised at the rookeries as readily as it can be at the abattoir, and there is no more necessity for molesting the females than there would be for a farmer to ship all of his herd to Kansas City and have the selection of the killable males made at the stock yards. The briefest recital of the facts of seal life will make this plain.

The facts of seal life.—The northern fur seals, unlike their southern relatives, are forced each year by Arctic cold and the necessity for food to leave their homes on the approach of winter and to seek the southern waters, and the abundant fish supply along the continental shores. The migration routes of the Alaskan and Asiatic herds do not coalesce, nor do the seals intermingle. Late in April or early in May, depending upon the character of the season, the breeding males, bulls, or "seecatchie," first return to their resorts from this migration. About a month later the mature females or "matkie" begin to seek the breeding-grounds, and between the time of arrival of these two classes the young males or "hollustchikie" are swimming in the water near the rookery fronts or hauling out upon the hauling-grounds some distance away from the areas occupied by the mature seals. The young males are not permitted to gather upon the breeding-grounds until, by reason of age and strength, they are able to maintain a position there.

Each old bull when he arrives in the spring selects and maintains, often by desperate combat, a little area upon which he hopes to establish his household. The male weighs four or five times as much as his consort, and, as is usually the case where the male preponderates in size, they are extremely polygamous. Their vitality and virility is almost beyond belief. For eighty or ninety days, while they are making secure their position, and while guarding and presiding over their families, or "harems," they are debarred from both food and water. When the season of propagation is past they again betake themselves to the sea, and the breeding-grounds are given up to the intermingling of young males, females, and pups, but during that eighty or ninety days the immature males from one to five years of age have been compelled to consort together upon the hauling-grounds, and thus there is given an opportunity without in any way interfering with the course of events upon the breeding-grounds, to drive away, select, and slaughter such of these young males as will furnish desirable pelts. These are the only skins shipped from the islands.

Can anyone successfully maintain that in the case of polygamous animals the taking of the surplus male life and reserving the females can destroy the herd? If this can be demonstrated, then our stock-raisers are at fault, and the evidence derived from Russian management goes for naught.

The facts of pelagic sealing.—Before the breath of life can be breathed into this theory of decadence through excessive killing on the islands there must be removed from the record books certain well-established facts concerning pelagic sealing. It will be necessary to dispose of the fact that while in 1878 there was but 1 vessel engaged in pelagic sealing, the number steadily increased until in 1892 there were 122 to follow on the migration tracks of the herds, to harry them eight months out of the twelve, and, if permitted, to accompany them to and even upon their chosen resorts. There must also be a successful refutation of the fact that there is a loss of at least 10 per cent inherent in the methods of taking seals at sea; that pelagic sealing strikes at the very life of the rookeries, by killing 75 or 80 per cent of the females, more than half of which are mothers whose death involves that of their unborn offspring; and that the period of gestation being nearly twelve months, a mother killed in Bering Sea means that three seal lives may pay the penalty.

It is equally important to the maintenance of this theory that there be an elimination of the fact that during the four seasons, ending with the past one of 1893, there were taken on the Pribilof Islands only a total of 50,000 skins of young males, while during that same period there were actually marketed by the sealers over 200,000 skins, which represented only about half the injury done the seal herds, an injury falling heaviest upon the producing class, the females. For four years there has been practically a closed time on these islands, and pelagic sealing has had full swing in the North Pacific. The rookeries have not improved under these conditions, and until the records of the real cause of destruction stand impeached it is idle to offer obscure and improbable explanations for the present condition of seal life.

It has only been profitable to follow this question of the cause of the decadence to indicate what might be expected from pelagic sealing. Whenever and to whatever extent carried on, its deadly effects are certain and continuous, the amount of injury being limited only by the magnitude of the enterprise. Improprieties on land can be guarded against, but the disastrous consequences of pelagic sealing are inherent to the business and are beyond man's control. They can be lessened, but only through the curtailment of the number of seals taken. The injurious effect upon the herd, while proportionately less, remains a constant factor.

In following the career of an animal possessing such capacity for self-perpetuation and ready adaptability to the uses of man, the student of natural history or of economics is struck by the wanton and needless destruction which pursues it wherever found. As to its future he turns, for what comfort he may be able to extract, to the decision of that court of recent if not last resort—the Paris tribunal of arbitration.

The Paris tribunal of arbitration.—The causes which led to the arbitration are known to all. For some years the Alaskan fur-seal, when on its migration route, had been the eagerly sought quarry of the pelagic hunters. This route, which by reason of its vast extent and proximity to inhabited shores makes this herd especially vulnerable to attack, extends from the Pribilof Islands southward through the passes of the Aleutian chain, expands in the broad Pacific, but ultimately brings the seals in more compact masses to the North American coast, and thence along its shores, back through the passes, to the Pribilof Islands again. Realizing the peril of the rookeries, the Government of the United States attempted to partially protect them by seizing sealing schooners in Bering Sea. Each year it was thought that at least so far as these waters were concerned the danger would cease, but each year it increased as the vessels multiplied and the skill and knowledge of the sealers became greater and was ultimately extended to the Asiatic herd which frequents the Russian or Commander Islands. The continued seizing of schooners by the United States met with remonstrances on the part of Canada and England, and finally, after much irritation and heat, became the subject of diplomatic negotiations, the peaceful outcome of which was the Paris tribunal of arbitration.

Three duties were intrusted to the tribunal of arbitration: It was to settle certain jurisdictional questions, to decide the question of property rights, and in the event of the matter being left in such shape that the concurrence of Great Britain was necessary to establish regulations for the purpose of protecting and preserving the fur-seal, it was to frame such regulations as would be applicable outside of the jurisdiction of the respective governments and to indicate the non-territorial waters over which these regulations should extend. As it is not important in this connection to consider the jurisdictional phases of the case there will be taken up at once the property question and the regulations—the two points that immediately concern us; the former from the standpoint of general interest, and the latter by reason of their intimate relation to the future of the seals.

The American position.—The able representatives of the United States took the position that the tribunal was bound by no precedents, and possessed, by virtue of its very origin, a creative as well as a judicial function. They urged upon the tribunal the taking of high ground and the settlement of the question upon broad and comprehensive principles. They pointed out that man, by means of invention, was rapidly extending his dominion over the water, as he had over the land, and, by employing methods which were not even dreamed of when many existing municipal and international laws were enacted, threatened the very existence of many creatures useful to man. Turning from the citations of voluminous authorities vindicating the justness of their claim of property right in the seals and in the industry, they pleaded with sturdy argument and great eloquence that the tribunal would fail of its high duty did it not lend its aid to such an extension of the world's idea of property right as was needed to meet the demands of the advancing age. They asked that the narrow ground be not taken that this great tribunal was called into existence solely for the purpose of settling a dispute between two nations, but that it was given an opportunity, and was vested with the power, to make a substantial contribution to international law, and that its verdict, while disposing of the immediate matter in dispute, should be such a formulation, upon broader lines, of our conception of rights of property and of protection as would be of value to all mankind, irrespective of nations. They pointed out that the material progress of the world was based upon the fundamental principle of ownership, and that the most effective way of preventing the commercial annihilation of certain great groups of creatures was by lodging in the nation best qualified by its geographic position to protect them a custodianship, to be exercised over them for the benefit of all. It was shown that the adoption of this principle would dispose of the question of the relation of other governments to the subject; would make possible the rehabilitation of many of the seal rookeries of the south; that it would protect such industries as the coral and pearl fisheries, and that it would be useful in controlling the rapid inroads man's ingenuity is now making on the denizens of the sea. In short, that it would be a direct, useful, and common-sense way of settling the whole matter.

The British position.—With equal skill of argument and eloquence of address the advocates of Great Britain and Canada held that the tribunal possessed but one function—that its duty was to declare the law and not to make it; but that, whatever its function might be as an international body, it was not vested with the power to make international law, but must keep to the straight and narrow way of settling a contention between two nations and adjusting two conflicting methods of catching seals. They asked that the tribunal provide for the continuation of pelagic sealing under the most favorable conditions consistent with carrying out the terms of the treaty. True, nothing was said in the treaty about preserving the business of pelagic sealing, but before so patient and generous a court it was not difficult to confuse the issue of preserving the seals and continuing pelagic sealing and to take up a large share of the proceedings with pleadings in behalf of the latter. They demanded that the question of property right be settled from the standpoint that the seals were wild animals, which man could only reduce to possession by destroying. They insisted that the law relating to wild animals, regardless of its origin, had been accepted by nations as the years ran on; it was very old law and very good law; but, whether good or bad, it was *the* law, and from its teachings the tribunal must not allow itself to be enticed away by the seductive citations and insidious arguments of learned counsel on the other side. There must be no making of laws to suit new conditions; the old stand-bys must be adhered to, whether applicable or not. They urged that the seals being wild animals, the United States had done nothing to encourage or develop in them the *animum revertendi*—the inclination to return to their homes, as in the case of bees and similar creatures—and thus had lost their claim to a property in them, and if the world or a part of it desired to turn out in boats and to destroy the industry by shooting the seals in the water they had a perfect right to do so, for a wild animal was free to all. No matter if seal mothers roaming the sea for food did fall before the gun or spear of the pelagic hunter and their helpless pups starve on the rookeries, the hand of destruction must not be stayed, for the United States had no rights anyone was bound legally to respect when the seals were three miles off shore, and humanitarian considerations had no place in the controversy. They insisted that the tribunal had no authority in law to declare a property right in the seals or in the industry, but if the tribunal contemplated disregarding the law and settling this question on lines of their own choosing they must refrain from doing so, because it would interfere with that wonderful invention, the immemorial right on the high seas, an interference nations not only would not brook, but which they would actively resent.

The tribunal's decision.—The tribunal, true to the conservatism of the Old World, accepted this interpretation of their powers, recognized the potency of venerable legal relics, assented to the arguments of the counsel for Great Britain and Canada based thereon, and contented itself with deciding that the United States had no right of protection or property in the fur-seals.

The regulations.—The next task to which the tribunal addressed itself, was the framing of regulations. These regulations furnish the last hope for the preservation of the fur-seal as a commercial commodity. It is not probable that any other nations having seal interests will be content with less than the United States secured, nor is it likely they will obtain more, and thus they represent the measure of protection all seals are likely to receive in the future.

After listening to an enormous mass of testimony, some good, some bad, and some very indifferent, concerning seal life, the tribunal proposes to preserve the Alaskan branch of the northern fur-seal by prohibiting sealing within a zone of 60 miles around the Pribilof Islands; by establishing a closed time, or time of no killing at sea, from May 1 to July 31; by permitting only sailing vessels to engage in the business of seal hunting, and requiring them to carry a distinctive flag, to take out a special license, and to keep a daily record of the catch and the sex of the seals taken, these records to be communicated to each of the two governments at the close of the sealing season; by limiting the weapons of capture to shotguns in the North Pacific and spears in Bering Sea; and by requiring the two governments to take such measures as will determine whether the hunters are fit to handle with sufficient skill the weapons by means of which the seals are to be captured. These regulations, which are to remain in force until they have been in whole or in part abolished or modified by common agreement between the Government of the United States and Great Britain, are to be submitted every five years to a new examination, so as to enable both governments to consider whether, in the light of past experience, there is occasion for any modification of them.

The three prime points in the regulations are: the zone around the islands; the closed time of three months injected into the middle of the sealing season, thus breaking it up; and the restriction of the use of firearms to the North Pacific.

First as to the zone: If there was any one fact clearly established by the testimony of the pelagic sealers themselves and official experts it was that in the summer season great numbers of seals, and especially females, are found at long distances from the islands of Bering Sea, distances two or three times greater than that of the protecting zone provided by the regulations. Now, as the object was to preserve the fur seals, it is proper to assume that the tribunal, prompted by a desire to protect them, and acting in good faith, established such a zone as they believed would practically prohibit the attack of the pelagic sealer; but if this were so, then mere amount of distance was immaterial, and in view of the fact that incessant fogs brood over the waters of Bering Sea during the summer season, rendering it difficult to tell when a vessel is within or without a zone, the limit of which can not be marked, why not at once adopt that natural and well-defined boundary line, the Aleutian chain? Just here arises the question:. When vessels are seized, whose word shall be accepted as to the locality of seizure, the pelagic sealer's or the seizing officer's? Does not this uncertainty, having as it does an important bearing on the question of conviction, weaken the regulations restraining influence on pelagic sealing? Aside from questions of protection it seems to me that this part of the decision will tend to increase dispute and bitterness rather than to diminish it.

The adoption of the closed time means the recognition on the part of the tribunal that the destruction by the pelagic sealer has been excessive and the cutting off of one month of the sealing season in Bering Sea clearly shows that it realized the danger to the herd from allowing sealing there. Why, then, was sealing not prohibited altogether in those waters? Is the danger less in August and a portion of September? The seals are still going long distances from the islands and the sealer can continue his work until stopped by the September gales. Bering Sea is the focal point, the great massing ground of seal life, and the seals are more readily taken there than anywhere else. In 1891 the catch of the Canadian fleet in the North Pacific was a little over 21,000 seals, and before the *modus vivendi* could be enforced a portion of the fleet sealed from three to five weeks on the American side of Bering Sea, and with fewer vessels and with fewer small boats they took in that time as many seals as they had previously secured in the Pacific. During the three years ending with and including 1891 the Canadian fleet (and I only quote from Canadian records, because they are so reliable) took, in five months, in the North Pacific, an average of 567 skins per vessel; with ten vessels less, they took in Bering Sea 727 skins per vessel in about two and one-half months.

The proposed regulations still allow at least five weeks' sealing in Bering Sea; but, say the regulations, the hunters can only use spears in Bering Sea, thereby intimating that spears are less effective than the shotguns allowed in the North Pacific, and that an additional safeguard has therefore been provided in Bering Sea. Just why the shotgun is pernicious in Bering Sea and is not in the North Pacific is not indicated; but if we turn to the testimony of the Northwest coast Indians, who ship on the schooners and accompany them to Bering Sea, we find that they claim that they can do better work with the spear than with the shotgun. The latter makes the game wild, while the former does not. The spear makes no noise, and they are thus able to take seal after seal as they sleep on the water, and get all in sight, while at the sound of a gun's discharge the comrades of the captured or wounded seal swim away.

It is evident from an inspection of these regulations as a whole that the Tribunal, taking into account the interests of both nations, endeavored to frame measures which, while protecting the seals, would permit the continuation of pelagic sealing. This seems to me a task the accomplishment of which is an impossibility. The evils of pelagic sealing appear to have been clearly recognized by the Tribunal, but instead of adopting prohibitive measures it took the middle course of throwing some protection around the seals and while at the same time appearing to concede something to the pelagic sealers, made the conditions just sufficiently hard as to prevent them from engaging successfully in the business. It is admitted that these regulations possess value in limiting and discouraging pelagic sealing, but their inherent weakness is that, while they now seem to possess some deterring power, changed conditions may at any time arise which will negative their influence and offer inducements sufficient to enable the sealers to again engage in this business on a large and injurious scale. This contingency is not so remote as may appear at first sight. In 1889 the average price paid in Victoria for skins taken at sea was $6.83; in 1890 it had risen to $10.70; in 1891 it was $15. In 1889 the cost of each skin in wages was from $2 to $3; in 1890 and 1891 it was $3.50; in 1892 it was $4. In other words an advancing price for both master and hunter.

Now, it is evident that it will be some time before the Pribilof Islands can very greatly increase their annual output of skins. The maximum output of the Commander Islands has been reached and probably will have to be decreased in the future. There must be through these regulations some curtailment of the contribution of the sealing schooners, and the result of all this will be that sealskins will demand a higher price. Should that price reach a figure which will compensate for the obstacles which the regulations place in the way of the pelagic sealer, then we will have the changed conditions referred to, and pelagic sealing with its attendant evils will go on as before. If there is doubt in the minds of anyone upon this point it is only necessary to turn to the history of the sea otter, which though nearly exterminated, is as eagerly sought after to-day as it ever was, simply because the ever-increasing price the trade is willing to pay for its skin still compensates for the small numbers now taken. There is no reason to believe that the career of the fur seal will be different from that of the sea otter.

Another possible source of changed conditions lies in the regulations themselves, for they provide, as we have seen, for their own modification every five years, and the pressure will come heaviest from the pelagic sealers' side of the case. Indeed the regulations require that each pelagic sealer—an interested party—shall keep records which are to be made available when the question of modifications of the regulations arises. Now, while there never was a more fearless and courageous set of men than these pelagic sealers it will be something entirely new in their history if their records do not appeal in the strongest possible terms for a modification of the regulations in their favor.

The final question that arises in regard to these regulations is, will they, as they now stand, ever be put in operation? The interested powers have yet to agree upon measures for giving effect to them. Is it likely that, when a neutral tribunal found the making of regulations so tedious and difficult, the interested powers will be able without interminable delay and possibly irreconcilable conflict to agree upon "concurrent measures" putting them in force? England has won on the great law points of the case, but these regulations are objectionable to Canada, for they bear somewhat heavily upon pelagic sealing; and these "concurrent measures" offer tempting fighting-ground for securing their modification in favor of the Dominion.

Under the circumstances it is only to be expected that the arts of diplomacy will be vigorously exercised in that direction. There is but one course, however, for the United States to pursue—permit no modifications, stand squarely for the prompt carrying out of these regulations, and let time reveal how much value they possess for protecting the seal herd. England will champion no plan of greater protection; she has all to gain and nothing to lose from delay, and it will require all the energy and firmness of the Executive to put effectively in force the regulations as adopted by the Tribunal.

Conclusions.—After more than two years of close study of this question it is my conviction that the only way in which the world can secure the largest benefit commercially from the fur seal wherever found is by taking the surplus immature males upon land under the most favorable conditions suggested by experience; that securing seals by any other methods introduces the fatal element of indiscrimination; that the life of the herd is jeopardized in proportion to the number of females killed; that the injury inflicted on the northern herds by pelagic sealing increases from January to August, grows greater as Bering Sea is approached, and culminates in those waters; that the shotgun and spear are both deadly, the latter by reason of its noiseless efficiency, the former by reason of its ready use by all classes, and that the disposition of this question on the basis of adjusting two conflicting interests is futile and illogical, but material issues are not alone involved; it presents biologic features as well and has to do with forces of nature beyond man's control.

Regulations can not be framed by human ingenuity which will preserve the seal herds in their greatest possible proportions and permit the continuation of successful pelagic sealing. It would be reconciling the irreconcilable. It would be accomplishing a feat equal to that of making two bodies occupy the same space at the same time. Either the regulations will be prohibitive in their operation—in which case it would be more straightforward to make them so in the first instance—or, if allowing successful pelagic sealing, they will be valueless in preventing the extermination of the seal. In general it may be said that *no* pelagic sealing can be carried on which is not inherently and uncontrollably injurious to the life of the seal herd—the amount of injury being proportionate to the magnitude of the attack.

42.—NOTES ON THE FISHERIES AND THE FISHERY INDUSTRIES OF PUGET SOUND.

BY JAMES G. SWAN.

ON THE ECONOMIC VALUE OF THE GIANT KELP AND OTHER SEAWEEDS OF THE NORTHWEST COAST OF NORTH AMERICA.

The giant kelp, which lines the shores of the northwest coast, is the *Nereocystis* of the order of *Laminariaceæ*. Harvey, in his Nereis Boreali Americana[*] thus describes this species:

> Olive-colored, inarticulate seaweeds, usually tough and leathery in substance. The plants of this order are almost always large, frequently of gigantic size, with a solid cylindrical stem, which expands into a hollow cylinder or tube, terminating in a globular head, from which fronds or aprons float on the surface of the water.

The *Nereocystis* of the northwest coast is said, when fully grown, to have a stem measuring 300 feet in length, which bears at its summit an air bulb, from which a tuft of upwards of fifty long, streamer-like leaves extend, each of which is from 30 to 40 feet in length. The stem, which anchors this floating mass, though no thicker than a common window cord, is of great strength and flexibility and has for ages been used by the natives as fishing lines, being first cut of the required length, which is where the stem begins to expand into the hollow tube, and varies from 10 to 15 fathoms, then soaked in fresh water in a running brook until it is nearly bleached, then stretched, rubbed to the required size, and dried in the smoke in the lodge. When dried, it is very brittle, but when wet, it is exceedingly strong, and equal to the best flax or cotton fishing lines of the white fishermen.

These pieces, varying from 10 to 15 fathoms each, are knotted together to the required length of 80 fathoms, required in the deep-water fishing around the entrance to Fuca Strait, or 200 fathoms at Queen Charlotte Islands, British Columbia, where the natives take the black cod at that profound depth.

Until within a few years the coast Indians used the upper or hollow portion of these great kelp stems as receptacles for holding dogfish oil which, together with the paunches of seals and sea lions and whale gut, properly prepared, were the utensils found in every house for holding the family supplies of whale, seal, or salmon oil which are used as articles of food, or for dogfish oil which is used for trading purposes only. Now, however, the Indians use coal-oil cans, barrels, and other utensils easily procured from the white traders, and the use of kelp for holding oil is nearly abandoned.

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[*] Smithsonian Contributions to Knowledge, May, 1858.

Among my collections for the National Museum in 1885, I received a number of specimens of this kelp which had been used for dogfish oil. I split one open and found that the oil had hardened the inside of the kelp tube to the consistency of leather. This specimen I washed with soap and water, then wiped it to remove the moisture, and then rubbed and manipulated it after the manner used by natives in dressing deer skins, and when perfectly dry by this process of continual rubbing, it was soft and flexible, presenting an appearance of wash leather, but if allowed to dry without manipulation it would be hard and brittle. A party of coast Indians were camped on the beach at Port Townsend, and, at my request, they showed me their method of preparing kelp for holding oil. The great stems of the *Nereocystis* are covered with a thin coating of silex, which is carefully peeled off as one might peel the skin from an apple; only the hollow or upper part of the stem is used. When the skin is removed the tube is placed above the fire and smoked in the lodge, and, as it dries, the salt it contains exudes on the surface; this is carefully removed by rubbing, which also serves to soften the kelp and render it pliable. It is then again placed over the fire, and the process continued until the salt is removed; then the tube is blown up like a bladder and allowed to dry until it will retain its shape, and it is then filled with dogfish oil and is ready for market.

The rude and simple experiments I made with this giant kelp convinced me that it is capable of being converted into articles of commercial value, but as I had not the means of conducting experiments or of procuring the machinery requisite to the manufacture of the kelp products on a scale of commercial importance, I have allowed the matter to rest until some one of enterprise and capital may be found, ready to continue these investigations

In order to show those who may feel interested in the development of this new industry, I will quote from a valuable and exhaustive paper "on the economic applications of sea weed," by Edward C. C. Stanford, F. C. S., read before the Society of Arts, London, England, May 22, 1884.

Sea weed as food.—In Great Britain little advance has been made in the use of algæ as food. The algæ contain important nitrogenous constituents and form nutritious articles of diet, but they have not been popular. We all like the smell of the sea air, but we do not cultivate a taste for our marine vegetables. The algæ, so far as known, contain no poisonous species. Among the edible varieties, *Ulva latissima*, or green laver, and *Porphyra lacinata*, or pink laver, are occasionally used in soups. *Rhodomenia palmata*, or dulse, is still sold in the streets of Edinburgh and Glasgow. *Aliara esculenta*, or murlins, is also eaten in Ireland. Some others are occasionally used, but as a general food the algæ are almost unknown.

The best-known British species of the edible algæ is the *Chrondus crispus*, or Irish moss; this grows far down on the rocks and is only uncovered at low spring tides. It is obtained mostly from the west coast of Ireland, and after being bleached by exposure to sun and rain is largely exported to England, Germany, and the United States. It is a gelatinous species containing a principle known as *carragheenin.*

The only other gelatinous British species is the *Gelideum corneum.* This is not very common, but furnishes the import known as Japanese isinglass, of which it contains 50 per cent. This substance, known also as gelose, was first imported into France from China in 1856; it has great gelatinizing powers, much higher than any other material; gelose has eight times the gelatinizing power of isinglass and gelatine, but the melting-point of the jelly is too high to melt quickly in the mouth, hence gelatine is still the favorite. The *Chrondus crispus* is found on the Atlantic coast and forms one of the industries of Cape Cod; it is also found on the Pacific coast from Cape Flattery to Alaska.

The green and pink laver and dulse are common, and constitute an article of diet of the Haida Indians of Queen Charlotte Islands and other tribes on the Northwest coast, who prepare these seaweeds by drying and pressing them into compact blocks. When required for food, these blocks are sliced with a sharp knife, then soaked in fresh water and boiled. The algæ are not in general use among all the tribes of the northwest coast, but they form a large article of food consumption in China and Japan.

The taste for marine vegetables must be acquired, but those who have eaten of them are said to become very fond of them, and some gentlemen in the Highlands of Scotland, personally known to Mr. Stanford "as no mean judges of diet, consider a dish of dulse boiled in milk the best of all vegetables." There is no doubt that a valuable food is lost in entirely neglecting the algæ. I have partaken of a meal of dulse boiled with halibut by the Haida Indians while on Queen Charlotte Islands, in 1883, and I found it very palatable. In Alaska and British Columbia the deer are fond of the sea mosses, and during the long run out of spring tides they eagerly browse the marine vegetable. Cows and pigs also eagerly eat the *Chrondus crispus*, and it has long been used by white people under its name of Irish moss.

The manufacture of seaweed.—The crude substance, which for many years made the Highland estates so very valuable, was first manufactured from kelp as the principal source of carbonate of soda. At the beginning of this century it realized from $100 to $120 per ton, and the Hebrides alone produced 20,000 tons per annum. The importation of barilla from the Mediterranean then began and the price fell in 1831 to $10 per ton. It was used, up to 1845, in the soap and glass works of Glasgow, until it was entirely superseded by the soda process of Le Blanc.

The manufacture of iodine and potash salts then began to assume some importance, but the kelp required was not the same; that which contained the most soda contained the least iodine and potash. Bromine is also extracted from kelp, but the amount is small and is not considered worth extracting, as large quantities are now produced in Germany and in this country from other sources.

The amount of iodine in sea water is so minute that it is extremely difficult to detect by ordinary tests, but the algæ possess the power of assimilating the iodine to about ten times the extent of the bromine. It is probable that all animal substances from the sea contain iodine; its presence has been very long known in cod-liver oil, but it is very small; the liver itself contains double as much, and fresh cod liver nicely fried has long been considered excellent in pulmonary complaints.

Algin, a new gelatinous substance.—All the algæ are cellular and contain no fiber, but properly treated they make a tough, transparent paper, which can be printed or written upon, like parchment. Stanford thus explains his process of extracting this substance:

If the long fronds of the *Laminaria stenophylla* be observed after exposure to rain, a tumid appearance will be noticed, and sacs of fluid are formed from the endomosis of the water through the membrane, dissolving a peculiar glutinous principle. If the sacs be cut, a neutral, glairy, colorless fluid escapes. It may often be seen partially evaporated on the frond as a colorless jelly. This substance, which is insoluble in water, is the remarkable body to which is given the name of algin. The natural liquid itself is miscible with water, but is coagulated by alcohol and by mineral acids. It contains calcium, magnesium, and sodium, in combination with a new acid, called alginic acid. When this natural liquid is evaporated to dryness it becomes insoluble in water, but is very soluble in alkalies.

This new substance is so abundant in the plant that on maceration for twenty-four hours in sodium carbonate in the cold the plant is completely disintegrated. The mass thus obtained is a glutinous mass of great viscosity, and difficult to deal with on that account. It consists of the cellulose of the plant mixed with sodium alginate. The cells are so small that they pass through many filters, but by cautiously heating it the mass can be filtered through a rough linen filter bag, the cellulose being left behind, and after the algin is removed this is easily pressed.

The solution contains dextrine and other extractive matter, and it is then precipitated by hydrocloric or sulphuric acid; the alginic acid precipitates in light gray albuminous flocks, and is easily washed and pressed in an ordinary wooden screw-press. It forms a compact cake resembling new cheese, and has only to be stored in an ordinary cool drying-room, where it can be kept any length of time. If desired, by adding a little bleach during the precipitation, it can be obtained perfectly white. The algin can be sent out in this state. It is only necessary to dissolve it in sodium carbonate in the cold for use. If, however, it be sent out as sodium alginate, it must be dissolved to saturation in sodium carbonate. The carbonic acid is disengaged and sodium alginate is formed. If potassium or ammonium carbonate be used the alginates of potassium or ammonium are formed, which are similar to the soda salt. The bicarbonates of these alkalis may also be used, but the caustic alkalis are not such good solvents.

The sodium alginate forms a thick solution at 2 per cent; it can not be made over 5 per cent, and will not pour at that strength. Its viscosity is extraordinary. It was compared with well-boiled wheat starch and with gum arabic in an ordinary viscometer tube. The strengths employed were as follows. It was found impossible to make the algin run at all over the strength employed:

	Seconds.
Gum arabic solution, 25 per cent, took 75	1 in 3
Wheat starch solution, 1·5 per cent, took 25	1 in 8
Algin solution, 1·25 per cent, took 140	1 in 112

So that algin has 14 times the viscosity of starch and 37 times that of gum arabic.

The evaporation is effected in a similar manner to that of gelatin, in thin layers on trays or slate shelves, in a drying room, with a current of air or on revolving cylinders heated internally by steam. High temperature must be avoided. The solution keeps well. Thus obtained, sodium alginate presents the form of thin, almost colorless sheets resembling gelatin, but very flexible. These sheets can be written upon or printed. It is said that in some parts of Japan this substance, which is translucent, has been used instead of glass to admit light to the dwellings of the poorer classes. It has several remarkable properties which distinguish it from all other known substances. It is distinguished from albumen, which it most resembles, by not coagulating on heating, and from gelose by not gelatinating on cooling; from gelatin by giving no reaction with tannin; from starch, by giving no color with iodine; from dextrin, gum arabic, pectin, and tragacanth, by its insolubility in dilute alcohol and dilute mineral acids.

The aluminum alginate is soluble in caustic soda, forming a neutral solution and giving on evaporation a substance like algin, but harder and making a stiffer finish. It is also soluble in ammonia, the salt becoming an insoluble varnish on evaporation.

The alginates of copper (*blue*), nickel (*green*), cobalt (*red*), chromium (*green*), are all soluble in ammonia and form beautiful, colored, insoluble varnish on evaporation.

Commercial application of algin or sodium alginate.—Algin being a soluble gum of considerable elasticity and flexibility is a great desideratum, and as a soluble substitute for albumen, which can easily be rendered soluble and used as a mordant, it is a valuable production.

As a finish, algin has the advantage over starch that it fills the cloth better, is tougher and more elastic, that it is transparent when dry, is not acted upon by acids, and it imparts to the goods a thick, clothy, elastic feeling without the stiffness imparted by starch. It has been used as a mordant in dyeing turkey red with remarkable success. The mordants when precipitated seem to have full dyeing powers, the results indicating that the substance is capable of taking the place of cow dung as used in print and dye works.

As an article of food.—Algin contains carbon, 44·39; hydrogen, 5·47; nitrogen, 3·77; oxygen, 46·37; or about the same amount of nitrogen found in Dutch cheese. It has a pleasant marine taste, easily overcome if objected to, and may form a useful addition to the kitchen for thickening soups and puddings. It appears specially adapted to replace gum arabic in the manufacture of jujubes and lozenges. To make into jelly requires addition of glucose or gelatin or admixture of lemon juice.

For boiler incrustations.—The sodium alginate has a remarkable effect on resolving and preventing the incrustation of boilers. It precipitates the lime in a state in which it can be easily blown off. The solution is pumped in with the feed water in the proportion of 1 pound to every 1,000 gallons; when hard waters are a necessity the saving of fuel is considerable. For salt-water boilers the sodium alginate is valuable and should be fully investigated.

Algic cellulose.—This substance bleaches easily, and under pressure becomes very hard, and can be turned and polished with facility. It also makes a good paper, tough and transparent, but with no fiber.

The process of extracting the algin and the cellulose utilizes the whole plant, and we obtain two new products of considerable commercial importance. The process is extremely simple, as already described, being a maceration of the plant for twenty-four hours in a solution of sodium carbonate in the cold; then filter and press. This operation does not require an extravagant plant, nor do operations on a large scale present any serious practical difficulties. The algæ of the Pacific coast are in such enormous quantities that the rudest kind of a building for shelter could be erected anywhere on the coast, or on Puget Sound near to the extensive fields of kelp, where it could be easily gathered at small expense and macerated in fresh-water solution of sodium carbonate, filtered, pressed, and made ready for the manufacturers.

During a residence of many years in the vicinity of Cape Flattery, at the entrance of Fuca Strait, I have had ample time and opportunity to observe the great masses of the giant kelp and other marine plants, which are torn up by the roots every fall by the storms, and piled by the waves along the beach at Neah Bay. I have frequently noticed, when a mass of this kelp has been thrown into a pool of fresh water, that in a few days it is covered with this slippery substance which Stanford has named algin, and I think that the *Nereocystis* is rich with this valuable ingredient. The supply of the raw material is practically unlimited, and if attention shall be directed to the valuable uses to which this plant and other algæ may be put, I feel confident that a new and important industry will be developed, and we would all share in the satisfaction of knowing that one more waste product of the ocean can be effectually utilized.

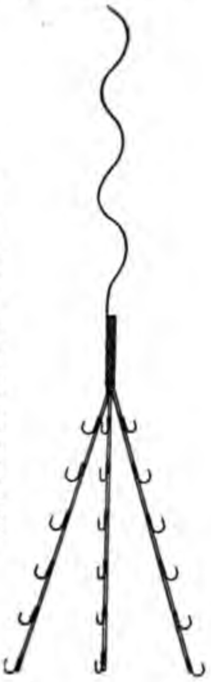
METHODS OF SECURING HERRINGS, SMELT, AND SARDINES AT PORT TOWNSEND, WASHINGTON.

The water of Port Townsend Harbor is as clear and transparent as the ocean. The only stream flowing into it is the Chemakum Creek, a small fresh-water brook at the southern end of the bay; the water of this creek is of too small volume and not sufficiently rapid to bring down muddy water and its effects are imperceptible, and the salt water of the bay varies but little in density and temperature from the ocean water at Cape Flattery, a hundred miles west of Port Townsend, and as a consequence the ocean fish, in their season, crowd in great masses into the bay and around the wharves where the clear water enables persons standing on the wharf to distinctly see objects at a depth of 25 to 30 feet.

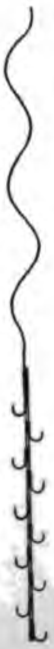
On a clear still day it is interesting to look down into the transparent water and view the myriads of fish. Cod and salmon abound in the spring and are easily caught with hook and line. The favorite bait for cod is a peculiar kind of a marine worm, which grows in clusters around the piles of the wharf; the bait for salmon is fresh herring. Cod and salmon swim the deepest and can be seen far down below the surface. Above them are the rockfish, then nearer the surface are herring, smelt, and anchovies or sardines. These are in such dense masses or schools that at times the water seems literally packed with them. Then the Indian comes slowly paddling his canoe and ever and anon making a dip with his fish-rake. This consists of a stout pole 15 or 16 feet long, with its lower end flattened like the blade of a paddle, into the edges of which are inserted a row of wooden pegs sharpened, or stout wire. The Indian takes the rake with both hands, as near the top as he can work, then reaches forward as far as he can and makes a swift stroke with the implement through the schools of fish, bringing it up behind him, and with a jerk he shakes off the fish which have been impaled on the sharp points or teeth of his fish-rake and they fall into the canoe. He will bring up from one to a dozen or twenty fish at a stroke, and keeps up the work until his canoe is full. This method has been used by Puget Sound Indians for generations before white men came among them, and long before the use of nets and fishing lines was made known to them, and is still a favorite method for procuring bait. They have, however, acquired the knowledge of making nets, and are expert in making nets and fish lines.

Formerly the twine for making nets was made of the fiber of the common nettle, and finer thread was made from the *Epilobium angustifolium*, or fireweed, so common all over the North American continent. The use of these materials seems to be abandoned at present, and is only found among some of the out-of-the-way bands of natives on the coast, where occasionally an old woman may be found who prefers to make and use the same material for threads as her ancestors used before the historic

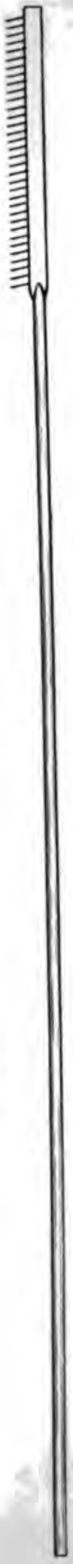
PLATE 17.



WIRE JIGGER ATTACHED TO FISH LINE.



FISH-LINE JIGGER.



HERRING AND SMELT RAKE USED BY INDIANS OF PUGET SOUND.

period; but twine and ready-made nets of the whites have superseded the primitive method, as hemp and cotton fish-lines have superseded the use of kelp lines made of the *Nereocystis* or giant kelp of the Northwest coast.

As herring, sardines, and smelt do not bite at baited hooks in these waters, the fishermen and boys that usually find sport or profit in fishing from wharves were not slow to adopt the Indian method of impaling them on the sharp points of fish-rakes. The Indian implement was found to be too clumsy to be used from the wharf, so a method was adopted of securing fish-hooks to lines, or to wires, which are termed jiggers. These are attached to fishing-rods. When used, the jigger is thrown out as far as it can reach and is then pulled swiftly through the masses of fish and is sure to impale several on the sharp hooks.

One instrument I have seen was formed of wires which would open and close like the ribs of an umbrella. This, when closed, would be lowered through a school of fish and when suddenly hauled up the wires would expand, and as each wire had a number of hooks attached to it a rich harvest was the result. This jigger method is a pot-hunter's plan, and is neither scientific from an angler's point of view nor does it have any other recommendation than that a hungry man can procure his breakfast with a few casts of a jigger into the dense schools of fish; but as the fish are more or less lacerated by this plan they are only fit for immediate consumption, and "jiggered" fish are not offered for sale by fish-dealers.

The smelt are taken for market by nets. They abound in Scow Bay or Long Harbor opposite Port Townsend, and the market is supplied by the fishermen who reside there, who are mostly Portuguese. These smelt are taken nearly every month in the year; they are of superior quality and very plentiful, but I never have seen them taken with hooks like the smelt of the Atlantic. The only way they are taken from the wharves is by these jiggers. The so-called black bass (*Sebastichthys*) is very plentiful and forms excellent sport. It is a game fish and fine eating, and at times is taken by the disciples of Izaak Walton with rod and reel, especially at night, in great quantities.

The bait used by these rod fishermen is either minnows, marine worms, salmon eggs, or fresh meat. The rod fishing for salmon from the wharves is excellent sport, and when salmon are running it is quite an attractive sight to see these fine fish landed in numbers on the wharves.

The anchovy are taken with smelt and herring in landing seines, but when a special fishery is established for these delicious fish they will be taken with purse nets in deep water where they school like mackerel.

This jigger system, which I have explained, is a proof of the enormous quantities of these fish in the waters of Puget Sound. Where fish are scarce the jigger is of little account and seldom used, but when the fish mass in myriads about the wharves the jigger is very effective.

ON THE SARDINE FISHERY OF PUGET SOUND.

The fish known on Puget Sound as sardines are not the *Clupea sagax*, or California sardine, but are the *Stolephorus ringens*, or anchovy. Of the California sardine, Prof. Jordan writes:*

> This species is everywhere known as the sardine, or, by the Italians, as "sardinia." It is, in fact, almost exactly identical with the sardine of Europe. It reaches a length of a little less than a foot. It ranges from Cape Mendocino to Chile, and is abundant south of San Francisco, especially in the winter, when it fills all the bays. In the summer it is scarce southwardly, although still taken northward. The young are, however, seen in San Diego in the summer. It is probably to some extent migratory along the coast, but as little attention is paid to it no definite data can be given. It is brought into the market when taken and is sold with the herring. The question of the possibility of canning it in oil has been considerably discussed. It would probably prove unprofitable, from the high price of labor and the uncertain supply of fish.

Of the California anchovy, Prof. Jordan writes:

> This species is everywhere known as the anchovy. It reaches a length of about six inches. It ranges from British Columbia to Chile, and is probably found on the coast of Asia also. It is found in sheltered bays, and is everywhere extremely common, but rather more abundant south of San Francisco than northward. It serves as food for the larger species to a greater extent than any other single species, and, in fact, a majority of the larger fishes make a large percentage of their food of anchovy. At San Francisco it is occasionally brought into the market. Some attempts have been made to pickle them for the trade with spice, but this amounts to little as yet. They have no economic value.

In the proceedings of the National Museum, volume IV, 1881, Prof. Jordan writes of the *Anoplopoma fimbria*, or black cod:

> From Monterey northward, generally common, especially in Puget Sound, when they are taken from the wharves. As a food-fish it is held in low esteem by the Chinese at Monterey, although sometimes fraudulently sold as Spanish mackerel. The large species taken in deep water about Vancouver Island, known to the Makah Indians as *beshow*, and by the whites as "black-cod," are highly valued as food-fish, according to Mr. Swan.

All the evidence that I have been able to collect from the reports of Prof. Jordan and other scientists, from fishermen and from my own observations, shows that the same species of fish, whether migratory or stationary, are richer in oil and other nutritious qualities the farther north they are taken. The black-cod, which is not considered worth eating at Monterey, is considered at Cape Flattery one of the most delicious food-fishes of the ocean, and at Queen Charlotte Islands, British Columbia, the natives procure from it great quantities of a peculiar fat, which, on cooling, becomes of the consistency of soft lard. This is used by the Indians instead of butter for eating, or is sold to other tribes for culinary purposes. The *Thaleichthys pacificus* (Richardson) or eulachon, sometimes called candlefish, when taken in the Columbia River, are not much fatter than a smelt, and are sold as smelts in the Portland markets, but when these fish are taken in Fraser River, British Columbia, they are rich with fat, and are considered most delicious eating, and at Victoria, British Columbia, are served up to epicures as a delicate pan fish. When taken still further north, at Nass River, British Columbia, near the Alaskan southern boundary, they are excessively fat and are taken by the Indians in immense quantities.' The fat is extracted and sold as "small fish grease." Its component parts are nearly identical with the grease of the black-cod.

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*Fishery industries of the United States, Sec. 1, 1884, page 569.

The same remarks are applicable to the anchovy. When taken in Monterey or San Diego bays, it is only fit for bait; but in Puget Sound, which is its northern limit, it is in perfection, and is one of the fattest and most delicious flavored of the small fish, and is considered by experts to be far superior, in point of flavor and richness, to the best Mediterranean sardine. Some Norwegian and Russian fishermen here have put them up, in limited quantities, in vinegar and spice, and they are delicious and sell readily; but the men who attempted the enterprise were without capital, and there has been no one with executive ability to push the business forward to a success.

The anchovy come to Puget Sound in enormous quantities, and during their season, from May to November, every bay and inlet is crowded with them. When they first come from the ocean they appear in Clallam Bay, on Fuca Strait, then in Port Angeles, Dungeness and Sequin bays, then in Port Discovery, and next in Port Townsend and Scow bays, where their numbers are almost incredible. I have known them to be in such masses at Port Hadlock, at the head of Port Townsend Bay, that they could be dipped up with a common water bucket, but as there has been no demand for them the fishermen do not consider them of value, and when hauling their nets for smelt they generally let the anchovy escape. The anchovy differ from herring in one respect—the herring, when they visit the bays, keep inshore and are easily caught in seines and landed on the beach; anchovies, on the contrary, keep out in deep water and seldom approach the shore, so that drag seines are of no use to capture them. They can be best taken with purse seines, as mackerel are taken in the Atlantic. As these fish are small, not much over 6 or 7 inches in length, they require a net with a small mesh, and with suitable gear an enormous quantity can be secured.

The only person I have known who has tried the experiment of putting anchovies in oil, like the French sardines, is Mr. Joseph O. Cates, of Port Townsend, fish-dealer. Mr. Cates formerly worked in the sardine canneries at Eastport, Me., and is an expert workman. He procured some tin sardine cans, and this summer put up a few dozen as an experiment and to show what he could do. Some were put up in California olive oil, and some in refined cotton-seed oil. The result proved a complete success, and demonstrated the fact that the anchovy of Puget Sound are equal in every respect to the best French sardines.

These fish were tested by experts, and were found to be delicious. It is difficult to perceive any difference between those put up in olive oil and those put up in cotton-seed oil. Capt. Z. L. Tanner, of the U. S. Fish Commission steamer *Albatross*, is of the opinion that for export purposes olive oil is preferable, as he informed me he had observed in the Eastport sardines that those put up in cotton-seed oil will, after awhile, acquire a peculiar taste which, although quite sweet, is not agreeable to every one, and is readily detected by experts; but as the so called sardines of Eastport are either young herring or the small fry of other species, the remark may not apply to the anchovy of Puget Sound, and time must be the only test. It is, however, conceded that these fish put up in pure California olive oil are equal to the best sardines the world can produce.

An opportunity is now presented to persons of capital and experience, for it requires both, to come here and start this industry on a scale which must insure success.

Port Townsend presents peculiar advantages. Not only do the anchovy swarm in the bay in their season, but in Scow Bay or Long Harbor, making up from Port

Townsend Bay, between the Marrowstone Islands, where, in those landlocked and sheltered waters smelts, herring, and anchovies abound. I have shown that in the waters of Puget Sound the anchovies are in their best condition, plump and very fat; and the failure of the experiments which Jordan says have been made to can these fish in oil at Monterey, San Diego, and San Francisco, where they are poor and of no commercial value, is no argument against the Puget Sound anchovy being put up in oil as sardines, as they are very fat and, as has been proved by the experiments of Mr. Cates, they are of superior quality and delicious flavor.

Should my remarks attract the attention of any persons desirous of engaging in the business of preparing sardines in oil, they should procure all their gear and machinery from the East. The purse seines, drag seines, and all fishing gear should be procured in Gloucester or Boston, Mass., and should be of the best quality and new. So also of the machinery for making the cans, soldering, etc. It should be of the latest and best designs, and procured of the best manufacturers. It is false economy to bring out second-hand or old-fashioned, discarded machinery. Everything should be the best approved in design and new.

Persons of experience in the sardine business know what would be the cost of a small plant, which could be increased as business demands, and they know what capital will be required; and this should be furnished entirely from the East. No one should come to Puget Sound expecting to secure capital, for it is not here; or bonuses, or donations, which, in the vernacular of the times, are "played out." The people of Puget Sound, and of Port Townsend in particular, have given away in bonuses, donations, and subsidies thousands of dollars for railroads, manufactories, and fisheries, which have produced no beneficial results. Those, therefore, who wish to engage in this lucrative business should do so entirely with eastern capital. Any one coming here with ample means to start the sardine business will find no difficulty in securing a suitable location on the most favorable and encouraging terms.

During the boom times adventurers, with small experience and with no capital but "cheek," came here to start fisheries, canneries, woolen mills, steel works, cement works, and other enterprises, relying upon subscriptions, donations, and subsidies for their capital, and every one proved a failure; and now those persons coming here without capital, seeking donations, are looked upon as frauds.

I have been thus plain in my statement because I know there is a means here for an immensely lucrative business in canning sardines in oil, which should attract the attention of eastern capital and experience. I do not advise inexperienced or impecunious persons to come here; we have plenty of such persons here already. But I do advise persons of means, and experience in the sardine business, to come here and examine into the truth of my statements, and I feel confident that I can convince them that I am correct.

43.—FISH NETS: SOME ACCOUNT OF THEIR CONSTRUCTION AND THE APPLICATION OF THE VARIOUS FORMS IN AMERICAN FISHERIES.

BY C. H. AUGUR,

Of the American Net and Twine Company.

We know of ten distinct devices for the capture of free-swimming fish—the spear, the snare, the hook, the dip net, the cast net, the seine, the pound, the gill net, the trammel net, the beam trawl. We think that any appliance called by any other name whatever will be found to embody the basic principle of one of these ten.

When, and in what order, and by what kind of fishermen these various methods were first conceived and brought into use we do not know. If we would trace their development from the beginning we must draw upon our imagination, for they are old devices; so old that history affords but little information as to their first conception. We know that certain birds and animals are expert fish-catchers, and we may imagine that the first fisherman imitated the salmon-catching bear, taking his piscatorial food from the water without other implements than those provided by nature in his strong arms and nimble fingers.

But it is an accepted fact that no fisherman was ever quite satisfied with his achievements, and we may assume that the primitive fish-catcher soon began to look with covetous eyes on the gamier fish; that he was sorely exasperated to see the finest specimens elude his grasp and swim with tantalizing dignity into the depths beyond his reach. Possibly it was one of these earliest fishermen who originally told how "the biggest fish got away," and it may have been the significant exchange of glances among his aboriginal cronies which fired him with determination to capture that biggest fish by fair means or foul in order to maintain his reputation for veracity.

What sort of an implement would be devised under such circumstances? Probably a spear; and it is not unlikely that for a long period of time after the introduction of this device our pioneer fishermen were to be seen furtively stealing about the banks of streams and the shores of the sea and lakes, practicing the "gentle art" by jabbing these cruel instruments into the flesh of their victims, or, when not thus engaged, devising improvements in the shape, style, and quality of their tackle—employing their time very much as fishermen do in the nineteenth century.

The snare has been referred to, not because it is now of any importance, but because it is a means of taking fish different from any other. It is one of the crude devices which would naturally suggest itself to a man without implements of any kind who should see a fine old fish lying between the rocks just beyond his reach. The nearest sapling would supply him with a pole, some twisted grass or bark fiber with cord to form a loop, careful adjustment of this to the tapering end of the pole, a little cautious manipulation of the tackle, the loop encircles the fish, is tightened by a sudden pull, and the victim landed flopping on the bank. We know from personal experience that nature has produced fish stupid enough to be taken in that manner.

Along with the spear and the snare some sort of a hook may have been devised, but we imagine that it was in the form of a gaff, and that the fishing industry was in a more advanced condition before the fish-hook, as we now know it, came into use.

The habit of many slow-moving fishes to rest lazily on the gravelly beds of shallow rivers, and of others to congregate at the head waters of streams in spawning season, and of still others to take temporary shelter in quiet nooks behind the rocks while ascending rapids, must have suggested the use of the dip net—first made, we may suppose, of woven grass attached to a bent sapling, afterward of leathern thongs or some stout vegetable fiber twisted into cord of suitable size and knotted into meshes.

All of these methods contemplated the capture of such fish as might be found in shallow water and in plain sight of the fisherman. Then we imagine arose the genius who first conceived the idea of luring the fish out of the safe places and inviting him to destruction by the offer of tempting food. We may suppose that bait was first used to attract the fish within range of the spear, and that afterward, as the result of another inspiration it was attached to a hook which the victim might take into his mouth. This was a tremendous advance in the development of fishing methods. Surely the catches increased enormously and intelligence of the new device must have spread rapidly among the tribes. We may confidently believe that at this time some of the old men seeing the jubilant and heavily laden fishermen returning day after day from the fishing-grounds originated the remark which has been handed down through the ages and which in its simplest form runs about like this: "If this thing keeps on the good fish will all be caught out of the water in about three years." Yet notwithstanding the dire predictions of disaster there was probably no appreciable diminution in the supply of fish, and the ingenuity of the fisherman continued to exercise itself in devising ways and means to still further augment the catch. It occurred to some one to apply the lure, or bait, in combination with the dip net: that is, to set a baited net of similar shape in the water resting on the bottom, to be suddenly raised when a number of fish had collected above the netting and were busily dissecting the food.

The time came when the possibility of capturing by one operation a large number of those fish which periodically visit the coasts and rivers in immense schools attracted the studious attention of the ambitious fisherman. These fish would not go to the bottom to feed on bait deposited in his dip net. Then, instead of spreading the net beneath them, why not throw it over them? This clever idea resulted in the device known as the cast net, which, from all the references to fishing nets in ancient writings, we believe to have been one of the earliest devices used by those to whom fishing was a means of livelihood. Yet it is not by any means one of the simplest devices, for the successful application of it requires great skill.

Another fisherman who seems to have lived before people began to record important events, devised the sweep seine. This form of apparatus may have been adopted either as a means of stopping and encircling large numbers of school fish passing along the coast, or as a method of capturing such fish as might be feeding upon grounds easily swept or dragged by a net of its character.

It was perhaps observed by some of the earlier seine fishermen that the immense schools of fish journeying along the coasts at certain times and seasons were often below the surface and invisible, and that they were intermittent, passing at unexpected hours when the fishermen were telling yarns or were asleep in their bunks; and from this observation the idea of the appliance which is known as the pound, or weir, may have originated. There is a belief current among our fishermen that the pound is of recent origin, but it is said that the American Indian used such a device, constructed of poles and brush, before the advent of the white man, and if that is true who can tell for how long a period this apparatus had then been employed. The belief that an aperture could be made opening into the pound which would not also be freely used by the fish as a means of exit, must have been founded upon a considerable knowledge of the nature of fish, and surely it was one of the distinctly original ideas in the history of fishing methods. It has been utilized in the construction of innumerable minor nets, among which are included a great variety of fykes and pots, although in the pot the idea of the funnel is applied in combination with the lure, and not with the leader; that is, the fish are attracted to it by bait, not driven in by obstructions to their natural progress.

In the net we have referred to are found pretty effectual means for the capture of all fish which swim near to the land, either in the sea or in the rivers. For those which inhabit waters of great depth, the gill net, quite distinct from all other nets, was devised and brought into extensive use. In this net the fish is not surrounded and dragged to the shore, nor lured by the use of bait, nor drawn from his course and led into captivity; he is required merely to run his head blindly into the meshes, which are composed of the finest twine or thread it is practicable to use in order that they may be as nearly as possible invisible.

A method differing from all the others referred to is found in the use of the trammel net. Like the gill net, the trammel may be stationary or allowed to drift with the current, but unlike the gill net it is so constructed as to catch fish varying greatly in size.

The shore fisheries having thus been provided with most effective apparatus, and the gill net devised for the high swimming ocean fish, there still remained for the attention of the net fishermen those fish which inhabit the deep waters, but do not rise far above the bottom. The beam trawl met this particular long felt want. It is, however, an apparatus more familiar to the fishermen of Europe than to us. There the beam-trawl fisheries equal in importance those of any other method, while here such experiments as have been made with them have proved unprofitable, and their use in the commercial fisheries is so limited as to hardly warrant consideration.

Now, if our attempt to account for the introduction of the various forms of fishing apparatus seems too fanciful, and does not accord with established facts, we are anxious to be enlightened by any one who knows better. The interesting fact is that all of the distinctive methods known at this time are of ancient origin; and it is a fact scarcely less noteworthy that every one of the appliances referred to, except the snare (and perhaps we should apologize for mentioning this device at all) is employed to some extent in the commercial fisheries of the United States even to this day.

The principle of the spear is applied in the whale and sword-fish fisheries. The spear in its simplest form is a common device successfully employed on fresh-water lakes in winter fishing through the ice, and in taking eels from the muddy beds of the shallow creeks and harbors along the seacoast.

The dip net in its original form yields profit to the Indian fishermen in certain salmon rivers on the Pacific coast. The finest whitefish served at the hotels in

Sault Ste. Marie, Mich., are taken by the same primitive device by the native Indian fishermen, whose birch canoes may be seen at almost any time far out in the foaming rapids, manned by two men, one poling the canoe steadily up stream, the other standing in the bow dexterously scooping the fish from the quiet pools behind the bowlders and rocks. In South Carolina also this form of net is used to capture shad in very much the same way as the Pacific coast fishermen take the salmon, that is, by continually plunging the net at random into the swift-running current, from a position on the bank of the stream, in such a way that one or more of the large numbers of fish passing upward to the spawning-grounds may run into it.

The Columbia River salmon wheel is an application of the dip-net principle; and the dip net used in combination with bait you may find in all sections of the country. Scores of them are in operation all summer long from docks about Chicago, supplying anglers with fine strings of perch for exhibition purposes at very reasonable prices.

The hook we all know is more extensively employed than any other device in the commercial fisheries, notably in the cod fisheries.

The cast net is found in common use along the southern coasts, more especially in Florida and the Gulf Coast States. Seines, pounds, and gill nets are three forms of apparatus of paramount importance in the American fisheries.

The trammel net is used chiefly in the great rivers flowing into the Gulf of Mexico. It forms one of the most important means of capture in the market fisheries of the Mississippi. The fyke is used in the same section of the country perhaps more extensively than in any other part, but this net is to be found on all the seacoasts and in the lakes and rivers.

The beam trawl, as we have intimated, has not been profitably employed here, but its use is known, and the same principle is applied in the oyster dredge. It is not our purpose, however, to discuss the methods employed in the shellfish fisheries.

Having referred generally to the various kinds of nets used in American waters, and supposing that all here present are familiar with the principles employed in their construction, it may nevertheless be proper to describe, very briefly, those which are of most importance.

Seining has been applied in America, as we believe it has nowhere else, to the offshore deep sea fisheries, by means of a contrivance for pursing the net. In the mackerel, menhaden, and salmon fisheries the purse seine is most extensively employed.

The menhaden purse seine is from 150 to 200 fathoms in length, and from 50 to 75 feet in depth. It is hung to double lines at the top and bottom, one right and the other left laid. The top line is fitted with corks sufficient in number to sustain the weight of the seine and float at the surface. At intervals along the bottom of the net iron or brass rings, about 3½ inches in diameter and a little less than one pound in weight, are attached to the hanging line. The purse line—Russia bolt rope, 1¾ inches in circumference—is passed through these rings. Two seine boats are used in operating the net, half of which is stowed in each boat. The boats are towed behind the fishing steamer, while cruising about in the waters where menhaden are known to be, until a school of fish is sighted at the surface, when they are manned and put off.

Having reached a proper position near the school of fish, the boats are rowed around it in a circle, starting in opposite directions, the seine being paid out as they proceed. When the fish are surrounded the crew of one boat enters the other, and all hands proceed to purse the seine—that is, to close the circle formed by the lower edge of the net by means of the purse line and rings, as the mouth of a bag would be closed by a puckering-string. The pursing is accomplished with the aid of a heavy, bell-shaped leaden weight dropped over the side of the boat, and having two blocks attached on opposite sides, through which runs the pursing line to the boat davits above. But it is quite impossible to describe this operation intelligibly without the aid of a sketch or model. When the seine has been pursed it is hauled aboard the boats until the fish are gathered into the bunt, when the steamer comes alongside and the fish are taken aboard by means of a bucket and derrick rigged on deck for the purpose.

This illustrates the principle of the purse seine. The difference in methods of application in the other fisheries is chiefly confined to the boats and vessels employed. A seine fashioned on this principle is said to have been operated off the coast of Rhode Island as early as the year 1826. It was a small net, and apparently was not a marked success, as nothing more seems to have been heard of purse seines until about 1860, since which time they have been in general use.

The pound, introduced into the commercial fisheries in Connecticut about the year 1850, and soon afterward adopted by the New England fishermen, has come to be very generally employed. On the Great Lakes it is found in the form which is perhaps most effective where the use of a tunnel is practicable. The leader of the lake pound is from 50 to 75 rods in length, the two heart webs each 9 rods in length, the pot 30 feet square, and the tunnel, running from the end of the heart into the pot, is of a length proportioned to the depth of water. The tunnel at the mouth is 30 feet wide, and of the same depth as the hearts, tapering to about 3 feet square at the small end, which extends 8 or 10 feet into the pot. The netting is hung in manila rope one-half inch in diameter. All the parts are held in position by poles driven into the bottom of the lake. The nets are set in the water varying from 15 to 75 feet in depth, and in a few cases they have been made to set from 90 to 100 feet deep. The upper lines of the leader and heart are even with the surface of the water. The pot extends 3 or 4 feet above the surface. In some minor particulars, such as the size of the lines, the opening in the tunnel, etc., the construction of the nets in some fisheries may differ slightly from the description we have given.

In the ocean pound, which has to contend with stronger currents and with floating seaweeds, the tunnel does not seem to be practicable. In its stead a second small heart is sometimes constructed, the converging point extending into the pot, leaving an opening from 2 to 10 feet wide between the poles.

In the weir, extensively used along the coast of the Eastern States, we have the same principle differently applied—round pots or bowls taking the place of the ordinary square pot, and the net being held in position by poles together with an elaborate system of guy ropes and anchors.

It is not practicable to give here more than these general particulars regarding the pound. The details of its construction vary in a hundred ways, according to the nature of the fishing-grounds and the ideas and whims of the fishermen.

Gill nets are employed in the fisheries in great variety. In the large rivers flowing to the ocean gill nets are used for the capture of those fish which ascend to the head waters in the spawning season. These river drift nets are employed chiefly for the capture of shad and salmon, and the methods of operation in taking the two kinds of fish are much alike. The nets, fitted with corks, buoys, and bottom weights are stretched across the river and allowed to drift with the current, following one another at frequent intervals. Drifting or floating gill nets have been used from the earliest times in the ocean fisheries for the capture of mackerel and herring.

Gill-net fishing on the Great Lakes is a very different operation. Here the nets are only about 4 feet in depth. They are hung to light cotton lines, heavily weighted, fitted with cedar floats to keep them in an upright position, and sunk to the bottom in water of any depth, varying from 10 to 75 fathoms. In the larger fisheries they are operated from steam fishing boats, each boat having an outfit of nets which, if fastened together and all set at one time, would stretch to a continuous length of from 20 to 30 miles. Gill nets of different proportions, but operated in a similar way, are employed in the cod fisheries of the seacoast States.

The mullet and shad gill-net fisheries of the Southern States have in recent years become very important, and from Florida to Maine the gill net is used to some extent for nearly all varieties of high-swimming marketable fish.

In the first half of this century the American fisheries, so far as they were carried on by the use of nets, were limited in extent. Gill nets and sweep seines were the principal means of capture employed, and they were operated along the Atlantic coast extensively enough to supply the local markets with fishery products, but except in the New England States they were not of great importance.

During the latter half of the century the development of net fisheries, encouraged by the growth and spread of population, with the consequent extension of markets, and by the perfection of transportation facilities, has been marvelously rapid. Gill nets stretch their interminable lengths throughout all the waters inhabited by edible fish—in the oceans east and west, in the rivers flowing into them, and in the great fresh-water lakes. Sweep seines, although for the most part abandoned in the great New-England fisheries, find profitable employment in other localities where they are better adapted to the fishing-grounds. They are to be found in large numbers and of great size on the Pacific coast. They form practically the only means of capture in the important net fisheries of the Gulf of Mexico. The capacity of the modern sweep seine is greater than the earlier fisherman would have believed possible. In the bays of North Carolina the seine sweeps several miles of fishing-ground at one operation, being paid out from the deck of a steamboat and hauled by steam power stationed on the land. The purse-seine steamers cruise about in the inexhaustible field afforded by the deep waters of the ocean. Wherever you may view a great expanse of water the black poles of the pounds, traps, and weirs attest the universal presence of these appliances. In its special field of operations the trammel net is numerously employed. Fykes, pots, small seines, and traps of multifarious form abound everywhere.

If it is true that during this period of remarkable expansion of the commercial fisheries no entirely new principle has been introduced in methods of capture; it is also true that the elaboration and application of old methods have been sufficiently progressive, and the observation of these changes is within the special province of the net and twine manufacturer, who views the whole field of operations and who is compelled to adapt his business to every new condition. Fishermen now living recall the time when half a dozen sizes of hemp twine of a rather ordinary quality sufficed for the requirements of all of the American fisheries. In the year 1893 there are between eighty and ninety different kinds and sizes of twine in constant use as material for netting, and the variety is increased to more than a hundred kinds and sizes if we include such as are used for gill-net hanging lines.

Previous to 1840 it had not occurred to anyone apparently to supply the fishermen with ready-made nets. In the twelve months of the present year the netting manufacturer whose business extends through all the fishing districts will have been called upon to supply more than three hundred distinct varieties of netting; that is, as many kinds as can be made up by the use of every conceivable size of mesh, duplicated in from two to thirty different sizes of twine.

More than thirty sizes of mesh and forty kinds and sizes of twine are required for the gill-net fisheries alone, the meshes varying from 1¾ inches (extended measurement) to 13 inches, and the twines from the size of a single horsehair to 36-thread cotton, which is nearly one-eighth inch in diameter. Of the great variety in sizes and twines referred to, all but a few are made of cotton, no hemp twine being used in our fisheries, and linen only where the yarn must be spun to extreme fineness, as in the gill-net fisheries of the Great Lakes.

The substitution of cotton for hemp twines in the American fisheries was a matter of very considerable importance, for its results were far-reaching, affecting the great fisheries of European countries hardly less than those of our own. The incident which led to this important step is here related:

Some time in the year 1844 a fisherman, known to history as Mr. McCarthy, whiling away an idle hour at a small store in Boston, where he bought his fishery supplies, expressed an opinion that somebody in this country might turn an honest penny by getting up a twine especially designed for nets, and better adapted to the purpose than the imported hemp twine then used. This proposition was discussed in the presence of Mr. James S. Shepard, who was then engaged in the manufacture of cotton yarns at Canton, Mass., and he very soon afterward submitted to Mr. McCarthy, the fisherman, a cotton twine which the latter made into gill nets and submitted in turn to the herring family of fishes for a final verdict. It was pronounced a satisfactory twine by Mr. McCarthy and was at once adopted by the fishermen, but candor compels us to say that the fisherman of the present day would not accept it as a gift. The best that can be said of it is that it was an improvement upon the hemp twine.

Soon afterward the popularity of cotton twines for both gill-net and seine fishing induced Mr. Shepard to devote his whole time to their manufacture and improvement. The product of his factory was taken by the proprietors of the store we have alluded to, who for some years had been supplying fishermen in a small way with nets made by hand knitters in and around Boston. This concern was the nucleus of the present American Net and Twine Company, and included Mr. Shepard in its membership a few years after the events narrated.

Aside from the introduction of the new twines, methods of manufacture did not undergo any considerable change for some years. Seines and gill nets continued to be the chief forms of apparatus, and the netting was made by hand, men, women, and girls being employed to do the work. The variety and sizes of twine and mesh were very small. The fishing industry was attaining considerable proportions, however, and the use of cotton twines stimulated a demand for them which induced other yarn manufacturers to engage in their production.

In the year 1858 the net and twine company referred to imported the first netting machine used in this country. It was a hand-power Scotch machine, the only kind then in existence. The Scotch machine was not then, and, we believe, it never has been adapted to the manufacture of heavy netting, so that after its importation all netting except that composed of fine twines continued to be made by hand. For light netting, however, the company built in their own factory several machines of the Scotch pattern.

The limitations of this netting machine led the Net and Twine Company to expend a very considerable sum of money in attempting to develop two or three inventions designed to overcome the difficulty of knitting heavy twines, but none of them proved satisfactory. In 1862 a newly invented machine, quite different in principle and well adapted to heavy work, was put in operation. Some years afterward an ingenious native of the State of Connecticut, Mr. Squire, invented a machine for knitting fine threads which possesses many advantages over the Scotch machine.

The larger netting companies are using the Scotch machine which has been improved somewhat in construction, and the 162-power machine, and the company we have spoken of use also the machine of American invention in the manufacture of fine thread netting, they having purchased the rights of the inventor.

The extensive introduction of these different machines was, of course, a process of gradual accomplishment, and while it was taking place the fisheries were undergoing that wonderful expansion which we have little more than indicated in this paper. Without the machines it would not be possible to produce the great variety of twine and netting used, and it is true, no doubt, that the ability of the netting factories to supply about everything imaginable has induced the fishermen to adopt a great many sizes of mesh and twine which would not otherwise be considered necessary.

We know quite well that what we have said about fish nets covers only a small part of the subject, and perhaps not the most interesting part. A chapter might be devoted to a description in detail of the methods of operating the various nets, to the multiplication of forms in nets having the same general principle, and to the frequent attempts, more or less successful, to apply new devices in parts of nets, such as the tunnels of traps, bags or cods in sweep seines and so forth. It is also proper to consider the effect of the multiplication of nets upon the supply of fish, but that is a matter which we are content to have discussed by those who are equipped with such knowledge of aquatic life--of the habits and nature of fishes, and of their capacity for self-propagation—as to make their opinions valuable. Unfortunately this equipment is not possessed by many who engage in public discussion of this subject; but we hope that much trustworthy information may be disseminated by those who take part in this congress.

44.—STATISTICS OF THE FISHERIES OF THE UNITED STATES.

By HUGH M. SMITH, M. D.,
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PREFATORY REMARKS.

The first satisfactory and reliable census of the fisheries of the United States was taken by the U. S. Fish Commission in 1879–80, under the direction of Dr. George Brown Goode, in the capacity of special agent of the Tenth Census. While in 1870 an effort was made to exhibit the extent of the fishing industry of the country, the attempt was acknowledged to be a failure and the published figures are concededly incomplete. The practical absence of statistical data for an earlier year than 1879 or 1880 is unfortunate, in that no basis for comparison exists between the present condition of some of our most important fisheries and their extent even at a comparatively recent date. A knowledge of the early variations in abundance as judged by the quantity of the catch is especially desirable in view of the marked changes in methods of capture in late years and the agitation of the question of the threatened extermination of certain fishes and other water animals. It is true that in the case of a few important fisheries, as, for instance, the whale and mackerel, certain valuable statistical data for long continuous periods have been furnished by customs-house, State, and private records, but for the great majority of our prominent fisheries and dependent industries and for all our minor branches no statistical information whatever exists showing their extent and importance prior to 1880.

The comprehensive canvass of the fishing industries of the country in 1880, so intelligently planned and so efficiently executed by Dr. Goode and his associates, and the complete statistical information based thereon that was given to the public, constituted an event of extreme importance in the history of our fisheries, independently of the equally valuable and exhaustive descriptive reports based on the same inquiry. These statistics, for their scope and form, as well as for the actual information conveyed, must remain the basis for comparison and the guide for the collection and preparation of future statistical data in the United States.

The importance of statistics in general needs no demonstration, and the value of statistical information regarding the fishing industry is certainly as great as that of any other branch of human enterprise. I may go even further and say that, on account of the uncertainties attending the prosecution of the fisheries and of the peculiar and unique conditions which prevail, there are few, if any, industries the exhibition of whose extent from time to time by accurate statistics is more desirable.

Fishery statistics seem to be particularly valuable and necessary in the United States, where the regulation of the fisheries is vested in so many legislative bodies; where the conditions vary so much in the different States, oceans, and lakes; where the variations in the abundance of certain products from time to time have been so noticeable; where the artificial culture of fish is so generally carried on and is conducted on such a large scale; where international complications over the fisheries have been so important and international relations are so intimate; and where the fisheries occupy such a prominent place among the national industries, on account of the large number of persons who find employment therein and the enormous additions to our food supply resulting therefrom.

The dependence placed upon fishery statistics by those who are connected directly or indirectly with the industry is attested by the avidity with which statistical reports are received and by the frequent demands for such data made on the Fish Commission by the general fishing public, State officers, economists, and national legislators. In the consideration of all important international fishery questions in recent years, in the enactment of State and federal laws affecting the fisheries, in gauging the effects of artificial propagation and the necessity for resorting thereto, statistics have played a very important part.

Mention should be made of the very creditable statistical work being done by several of the States through fish commission boards and industrial and statistical bureaus. Massachusetts, Connecticut, Maryland, and doubtless other States have made valuable contributions to the literature of fishery statistics, and many of the fish commissions have from time to time presented original statistical information of importance in their annual reports.

The figures presented in this paper have been obtained by the U. S. Commission of Fish and Fisheries, and represent the personal inquiries of its statistical field agents. That office has a permanent force trained for the collection and compilation of the statistics of the ocean, shore, river, and lake fisheries of the country, and is better prepared for this work than is the Census Bureau, which takes up the subject only at intervals of ten years and with the services of persons who, as a rule, have had no previous experience in the work and whose interest therein ceases with the disbandment of the bureau.

At an early period in the history of the U. S. Fish Commission the desirability of having full and accurate statistical information concerning our fisheries was realized and in one noteworthy instance, at least, was forcibly exemplified: The absence of reliable figures by which to substantiate the American claims in the Halifax Commission has been generally regarded as one of the prime reasons for the adverse decision of that tribunal and the award of $5,500,000 to Great Britain.

The necessity for having statistical data was fully appreciated by Prof. Baird, the founder of the Fish Commission and its honored head for seventeen years, and various minor inquiries, such as the means at his disposal would permit, were undertaken by him in the years preceding the Tenth Census investigations. From 1880 to 1885 a small sum was annually appropriated by Congress for carrying on statistical work. For the fiscal years 1886, 1887, and 1888, no special allotment was made by Congress, the general appropriation for the Fish Commission being apportioned among the various branches of the work, at the discretion of the Commissioner. Under this arrangement, the statistical work received more substantial recognition than had been previously accorded, and in the last year named extended inquiries were made relating to the statistics, methods, and relations of the fisheries. The organization of a separate force for the collection and compilation of statistics may be said to date from 1886, although it was not until the following year that a special division for this work was established. After the death of Prof. Baird, in 1887, ample encouragement was accorded the statistical service by his successors, Messrs. Goode and McDonald, and in 1888 this work was specially noticed and appropriated for by Congress; since that year a specific sum has been annually allotted.

While Congress has thus evinced an appreciation of this work and exhibited a desire to deal liberally therewith, it requires but slight consideration to show that the means and force available for the service are entirely inadequate to properly conduct the investigations and to secure the publication of their results with satisfactory promptness. To place the fisheries statistical service on an ideal basis, which would permit an annual or biennial study of the entire fishing interests of the country, would require a field force nearly five times as large as the present one and an appropriation twice as great as that for 1893. The shore line of the States bordering on the coasts, coast rivers, and Great Lakes is not less than 30,000 miles in length; and there are few long, continuous stretches of beach or shore that do not support fisheries of greater or less importance, the investigation of which requires the personal presence of the field agents. The canvass of the extensive territory in which commercial fishing is carried on can not be accomplished in less than three or four years. This accounts for the fact that the statistics available do not strictly relate to a single year, but apply to the years 1890 or 1892, although, for all practical purposes, the figures may be regarded as representing the present condition of the fishing industry.

The fisheries of the interior rivers and small inland lakes of the United States have never been thoroughly investigated. Even in the exhaustive canvass under the direction of Dr. Goode in 1879-80, no satisfactory account of these fisheries was obtained, owing to lack of time and means, and our entire statistical knowledge of their extent is given in an estimate by Dr. Goode that they are worth about $1,500,000 annually. This is believed to be much less than the actual figure at the present time, and it would not be especially surprising if inquiries would show that the products resulting from professional and desultory fishing in the minor fresh waters would have an annual value of nearly $5,000,000. The importance of these inland waters as sources of food supply is great and increasing, and the Commissioner of Fish and Fisheries proposes to begin an investigation of their extent, methods, and needs at an early date.

With these prefatory remarks we will proceed to a consideration of the condition and extent of the fisheries of the United States as shown by the figures presented, and will endeavor to interpret, so far as may be necessary, some of the facts brought out in the tables.

GENERAL IMPORTANCE OF THE FISHING INDUSTRY.

The full extent of the fisheries of the United States has not been exhibited by detailed figures since the results of the census of 1880 were published. In the year named the number of persons directly connected with the industry was ascertained to be 131,426; the amount of capital invested in the business was $37,955,349; and the value of the catch was $38,683,348. While the increase in the population of the country since that time has naturally led to an advance in the fishing industry entirely independent of the fluctuations in the abundance of economic water animals, few persons are aware of the great importance of the fisheries at present, and still fewer are informed regarding the changes in the development of our fishery resources since 1880.

Compared with many other great national industries, fishing may justly be considered of minor importance. In a number of the coast States, however, this industry ranks among the foremost enterprises. In view of the international questions affecting the entire country which have arisen and are likely to arise in connection therewith, and because of the great amount of attention which the fisheries have received and are still destined to receive from State and national legislatures, fish commissions, and other organizations, fishing deserves to be regarded as one of the leading industries of the nation, and, as such, entitled to the most careful consideration and study.

At the present time, the general extent of the fisheries of the United States, as determined by the investigations carried on by the U. S. Commission of Fish and Fisheries, is as follows:

Persons employed	182, 376
Capital invested	$58, 245, 406
Value of products	$45, 312, 818

THE FISHING POPULATION.

While the statistics show that the number of persons in the United States directly connected with the fisheries is under 200,000, when cognizance is taken of the large number of people engaged in various other occupations directly or indirectly dependent upon the fisheries and of the fishermen's families who are immediately supported by their labors, it is safe to assume that the fishing industries of the United States give support to over 1,000,000 men, women, and children, or about 1 person in every 65 of our population.

Of the persons connected with the fishing industry, 37,800 are vessel fishermen, 105,000 are shore and boat fishermen, and 39,200 are shoresmen and factory hands.

The State having the largest number of persons employed in the fisheries is Maryland, where 39,900 people are directly associated with the fishing industry, chiefly in the oyster-packing business. The State with the next largest fishing population is Virginia, which is credited with 23,595 persons, a majority of whom are connected in some way with the oyster industry. Massachusetts follows Virginia with 17,025 persons, more than half of whom are vessel fishermen, a class more numerous here than in any other State. Maine ranks next to Massachusetts; its fishing population numbers about 15,100. Other States having more than 10,000 fishery employés are New York, with 13,750; New Jersey, with 10,435; and North Carolina, with 10,275.

Of the geographical regions, the most important as regards the number of fishery employés is the Middle Atlantic, where about 90,700 persons are engaged, of whom 17,750 are vessel fishermen, 54,600 are shore and boat fishermen, and 18,350 are shoresmen. The next important region is New England, which has 37,000 fishing population, consisting of 14,300 vessel fishermen, 13,400 shore and boat fishermen, and 9,300 shore hands. The other sections, in the order of their rank, are the Pacific States, including Alaska, with 16,800 persons; the South Atlantic States with 16,000; the Gulf States with 12,000, and the Great Lakes States with 9,750.

The following table shows, by States and geographical sections, the number of persons employed in the different branches of the fishing industry:

Persons employed in the coast and Great Lakes fisheries of the United States.

States.	Vessel fishermen.	Shore and boat fishermen.	Shoresmen, factorymen, etc.	Total.
New England:				
Maine	2.608	6,840	5,680	15,128
New Hampshire	135	210	28	373
Massachusetts	10.175	4.178	2,672	17,025
Rhode Island	403	954	227	1,584
Connecticut	992	1,213	710	2,915
Total	14,313	13,395	9,317	37,025
Middle Atlantic:				
New York	2,346	7,858	2,042	12,246
New Jersey	2.337	7,560	536	10,433
Pennsylvania	295	1,615	310	2.220
Delaware	109	1,692	446	2,247
Maryland	8,342	19,867	11,735	39,944
Virginia	4,308	16,027	3,260	23,595
Total	17,737	54,619	18,329	90,685
South Atlantic:				
North Carolina	426	7,052	2,796	10.274
South Carolina	74	2,503	124	2,701
Georgia	64	1,357	201	1,622
Florida	6	1,305	230	1,541
Total	570	12,217	3,351	16,138
Gulf:				
Florida	1,085	2,784	466	4,335
Alabama	93	416	109	618
Mississippi	203	487	1.031	1,721
Louisiana	332	3,276	460	4.068
Texas	84	1,032	161	1.277
Total	1,797	7,995	2,227	12.019
Pacific:				
California	1,850	3,007	569	5,426
Oregon	90	2,651	1,459	4,200
Washington	376	3,010	910	4,296
Alaska	346	1,012	1,491	2,849
Total	2,662	9,680	4,429	16,771
Great Lakes:				
New York	32	1,346	120	1,498
Pennsylvania	95	250	58	403
Ohio	192	1,733	813	2,738
Michigan	250	2,693	400	3,343
Indiana	5	89	....	94
Illinois	12	309	65	386
Wisconsin	126	956	143	1,225
Minnesota	19	17	15	51
Total	731	7,393	1,614	9.738
Grand total	37,810	105,299	39,267	182,376

One of the most interesting questions connected with the consideration of the fishing population is the extent to which persons of foreign citizenship engage in our fisheries. Especially important is a knowledge of the foreign element in the fishery marine. The inquiries on which the present paper is based have been addressed to this subject in every region. It appears that the largest proportion of foreigners is found in the vessel fisheries of the Pacific States. The vessels sailing from South Atlantic ports are manned wholly by citizens. The percentage of foreigners in the vessel fisheries of the entire country is 21. In the New England States the vessel fishermen consist of 71 per cent United States citizens, 15 per cent British provincials, and 14 per cent other foreigners, chiefly Portuguese. Ninety-two per cent of the vessel fishermen of the Middle Atlantic States are native-born or naturalized citizens, the 8 per cent of foreigners being made up largely of Germans, Swedes, and Norwegians. Natives of the Bahamas and other British possessions constitute 34 per cent of the vessel-fishing population in the States bordering on the Gulf of Mexico; 13 per cent of other foreigners in the same region are chiefly Spaniards. On the Pacific coast, only 44 per cent of the vessel fishermen are United States citizens; 15 per cent owe allegiance to the British flag, and 41 per cent are of other nationalities, Austrians, Norwegians, Swedes, and Italians predominating. In the vessel fisheries of the Great Lakes, 86 per cent of the fishermen are citizens, 5 per cent are British provincials, and 9 per cent are of other nationalities, chiefly Norwegians and Swedes.

The following is a tabular statement of the foregoing facts:

Percentage of citizens and foreigners on fishing vessels of the United States.

Sections.	United States.	British Provinces.	All other countries.
New England	71	15	14
Middle Atlantic	92	1	7
South Atlantic	100	....	....
Gulf	53	34	13
Pacific	44	15	41
Great Lakes	86	5	9
Total	79	8	13

THE VESSELS, BOATS, APPARATUS, AND CAPITAL.

From the appended table (pp. 397, 398) it appears that the amount of money invested in vessels, boats, apparatus, buildings, wharves, and other property connected with the commercial fisheries is about $58,245,000. Of this sum, $19,860,000 belongs to the New England States, $19,405,000 to the Middle Atlantic States, $8,873,000 to the Pacific States, $5,421,000 to the Great Lakes, $2,993,000 to the Gulf States, and $1,693,000 to the South Atlantic States. The States having the largest investments devoted to the fisheries are Massachusetts, with $12,980,000; Maryland, with $7,465,000; New York, with $5,981,000; Virginia, with $2,944,000; Maine, with $2,882,000; Connecticut, with $2,869,000; Alaska, with $2,536,000; California, with $2,526,000; New Jersey, with $2,518,000, and Oregon, with $2,220,000. Other States having over $1,000,000 invested are Rhode Island, North Carolina, Florida, Washington, Ohio, Michigan, and Pennsylvania.

The aggregate number of vessels employed in the fisheries is 6,334; these, with their outfits, have a value of $14,300,547, and represent a combined tonnage of 176,783. About three-fifths of the vessels, or 3,931, belong in the Middle Atlantic States and about one-fourth, or 1,500, in the New England States. The Gulf States have 404, the Pacific States 202, the South Atlantic States 169, and the Great Lakes States 128. The largest tonnage and greatest value are found in the New England States, where the average size of the vessels is much larger than in the Middle Atlantic region. Every State bordering on the coast waters or Great Lakes has a vessel fishery of more or less importance. The least extensive fishery of this class, as judged by the number of vessels, is in Indiana, where only one vessel was employed. The State having the largest fishing fleet is Maryland, with over 1,600 vessels; the State occupying the second rank is Virginia, with 944 vessels, followed by Massachusetts with 809, New York with 666, New Jersey with 618, and Maine 397. The tonnage and value of the vessels of Massachusetts are greater than in any other State, after which come Maryland, Virginia, California, Maine, Alaska, New Jersey, New York, and Connecticut in the item of tonnage, while in point of value the order is Maryland, California, New York, Virginia, New Jersey, Connecticut, and Maine.

The number of boats used in the fishing industry, exclusive of those which form a part of the outfit of the vessels, is 66,464, valued at $4,382,520. More than half the boats are employed in the Middle Atlantic States. The boat fisheries are especially extensive in Maryland, where there are 9,800 boats. Other important States in this respect are Virginia with 9,250 boats, New York with 7,515, Maine with 6,015, and New Jersey with 5,590.

Foremost in point of value among the forms of apparatus used in the capture of fish and other products stands the class of appliances of which the pound net is the type, and which includes the pound net, the trap net, and the weir. The number of these employed in the United States is 8,726, with a value of $2,189,526. This kind of apparatus is most numerous in the Great Lakes, where 3,750 nets, mostly the typical pounds, were set in the year covered by the figures, 1890. The next important region is the Middle Atlantic, to which 2,445 such nets are credited. New England has over 1,100 such traps, the South Atlantic section 960, the Pacific Coast 432, while in the Gulf States this form of net is not used. The individual States in which the fishery with pounds, traps, and weirs is especially extensive are Michigan, Ohio, Maryland, North Carolina, Virginia, Maine, New York, Wisconsin, Massachusetts, Oregon, and Washington.

The most extensively used apparatus is the gill net, which in value closely approximates to the pound net. The number shown in the tables is 244,942, with a value of $1,728,266. As the nets of this class are of such a varying length, even in the same fisheries and the same localities, a statement of the length of gill-netting employed will convey a better idea of the enormous extent of this fishery than a mere enumeration of the number of separate pieces. A close approximation, based on actual figures in the great majority of cases, gives the aggregate length of the gill nets as 51,446,000 feet, or 9,743 miles. Gill nets are used in greater or less numbers in every geographical section, but are most numerous and represent the largest investment in the Great Lakes, where over 100,000 nets, worth $498,096, are reported. Next in rank in the number of gill nets is the South Atlantic region, which is credited with over 93,000 nets, although their value, only $204,227, indicates their relatively small size. The Middle Atlantic States have about 32,000 nets, valued at $419,858. In the New England fisheries 12,000 such nets, worth $112,201, are employed. The number of these nets on the Pacific coast, 5,023, is relatively small, but their value, $467,021, shows them to be of larger average size than in any other region. The gill net is rare in the Gulf region, less than 900 being there operated. The States in which the gill net is especially conspicuous are North Carolina, Michigan, Pennsylvania, Ohio, Wisconsin, New York, and Maryland, each of which has over 10,000; while, on account of the value of the catch, this form of apparatus is also important in Maine, Massachusetts, New Jersey, Virginia, Florida, California, Oregon, Washington, and Alaska.

Seines rank next to gill nets in value. The 5,165 such appliances shown in the table had a value of $761,286. The seines are most numerous and important in the Middle Atlantic States; 1,789 are there employed, having a value of $276,691. In the South Atlantic States this apparatus is nearly as numerous as in the region first named, but the average value of the nets is less; 1,503 seines credited to that section were worth $111,819. The New England States are credited with 640 seines, valued at $190,405. On the west coast 461 seines, having a value of $108,885, are in use. The seines in the Gulf region are nearly as numerous as in New England, but the average value is only one-fourth that of the other section. Seines are not prominent in the Great Lakes; only 154 are there owned, and the investment in that form of apparatus is only $17,236. The most important seine fisheries, as determined primarily by the number of seines operated, are in North Carolina, Maryland, New Jersey, New York, Florida, Massachusetts, Maine, Virginia, Delaware, and California, the first-named State having nearly one-fourth of all the seines used in the United States.

Nearly equal to seines in point of value are the hand lines, trawl lines, and other lines employed in fisheries of all sections. The New England States, with their enormous ocean fisheries carried on chiefly with lines, would naturally be expected to lead in this item, and it appears that of the $708,000 invested in this class of apparatus the region in question has $620,000. The other sections in their order of importance are the Pacific, Middle Atlantic, Gulf, Great Lakes, and South Atlantic.

The dredges, tongs, and rakes employed in the molluscan fisheries represent an outlay of $561,000, of which $477,000 is to be credited to the Middle Atlantic States, the section having the most extensive oyster fishery.

Ranking fourth in importance among the various classes of nets used in the fisheries of the country are the fykes, although their aggregate value is much less than that of any of the forms of apparatus thus far specified. Over 24,000 fyke nets, whose value is $222,000, are set in the coast and lake regions. The fykes are relatively important only in the Middle Atlantic States, although in the Great Lakes and in New England rather extensive fisheries are in places thus carried on. In the region first named over 20,000 fykes are used, having a value of $119,000. This appliance is absent from the Gulf States, and is of little consequence in the South Atlantic and Pacific States.

The numerous other kinds of fishing apparatus not separately designated in the accompanying table, and not so generally used as those specified, have a value of about $565,000. Among these are pots, wheels, cast nets, spears, harpoons, and many other minor appliances. The Pacific and New England States contain the great bulk of this miscellaneous apparatus.

The shore and accessory property connected with the fisheries and the related shore industries represents a very large investment in every region, amounting in the aggregate to over $16,000,000. This sum includes the value of fish houses, wharves, fishing camps, and other buildings and structures necessary for the prosecution of the business: fish cars, reels, live boxes, floats, etc. In the New England States the investments in such property are larger than in any other section, amounting to $5,887,000. Closely following New England is the Middle Atlantic section, where the shore and accessory property has a value of $5,816,000. On the Pacific coast $2,400,000 is thus invested, and in the Great Lakes region $1,635,000. The South Atlantic States have $436,000 and the Gulf States $677,000 thus devoted to the fishing industry. Four States have over $1,000,000 shore property directly connected with the fisheries; these are Massachusetts with $3,098,000, Maryland with $2,446,000, New York with $1,724,000, and Connecticut with $1,605,000.

Properly included in the fishery investment is the cash capital, or working capital, required to properly conduct the industry. This amounts in the aggregate to nearly $16,000,000, corresponding closely with the capital represented by the shore property, being greatest in the New England States and least in the South Atlantic States.

In this item Massachusetts leads all other States with $4,175,000, followed by Maryland with $2,107,000, New York with $2,093,000, and Alaska with $1,139,000.

Table showing the apparatus, vessels, boats, and capital employed in the fisheries of the United States.

States.	Apparatus of capture.										
	Pound nets, trap nets, and weirs.		Gill nets.		Fyke nets.		Seines.		Value of lines.	Value of dredges, tongs, and rakes.	Value of other apparatus.
	No.	Value.	No.	Value.	No.	Value.	No.	Value.			
New England:											
Maine	700	$137,331	7,565	$55,070	136	$559	232	$35,395	$89,690	$3,140	$141,279
New Hampshire	6	300	84	1,197			6	1,750	1,200	11	2,986
Massachusetts	179	207,583	4,240	44,772	15	100	306	129,050	525,860	10,240	35,406
Rhode Island	174	83,145	115	7,500	4	320	50	17,295	2,639	8,372	10,930
Connecticut	90	28,620	79	3,662	450	2,380	45	6,915	1,080	32,275	25,542
Total	1,149	456,979	12,083	112,201	605	3,359	639	190,405	620,469	54,038	216,143
Middle Atlantic:											
New York	263	71,340	7,507	88,450	6,246	55,465	327	75,640	11,515	119,912	21,369
New Jersey	234	83,913	3,941	129,791	1,488	13,706	366	37,118	4,808	71,917	10,362
Pennsylvania			205	21,200	2,532	5,219	141	18,750	534	4,025	488
Delaware	27	455	1,603	34,373	540	1,220	199	10,083	20	2,787	1,097
Maryland	1,005	71,778	11,999	100,014	9,366	37,924	536	76,780	2,272	198,920	6,511
Virginia	916	162,690	6,979	46,030	339	5,770	220	58,320	3,462	79,525	547
Total	2,445	390,176	32,234	419,858	20,511	119,304	1,789	276,691	22,611	477,086	40,374
South Atlantic:											
North Carolina	950	80,394	90,980	154,582	36	384	1,273	99,649	57	4,457	4,755
South Carolina			1,380	13,958			74	4,008	562	1,116	2,464
Georgia	5	1,250	398	7,957	11	285	51	2,052	306	898	1,757
Florida	5	570	468	27,730			105	6,110	630	280	6,508
Total	960	82,214	93,226	204,227	47	669	1,503	111,819	1,555	6,751	15,484
Gulf:											
Florida			740	19,688			205	15,390	3,652	3,019	12,136
Alabama			66	6,620			30	2,730	102	1,803	295
Mississippi			15	555			80	6,680	3	3,199	48
Louisiana							168	14,600	9,176	8,915	13,472
Texas							136	16,850	540	2,606	3,935
Total			821	26,863			619	56,250	13,473	19,542	29,906
Pacific:											
California			2,476	112,221	49	980	191	22,635	15,954	575	66,382
Oregon	249	175,000	1,379	211,660			32	12,600	10,670	145	135,327
Washington	157	124,700	845	110,390			163	46,725	5,855	3,492	60,279
Alaska	16	10,500	323	32,750			76	26,925	6,150		500
Total	422	310,200	5,023	467,021	49	980	461	108,885	38,629	4,212	262,488
Great Lakes:											
New York	325	29,427	6,927	52,932	684	9,822	32	781	1,989		129
Pennsylvania	200	29,270	22,370	72,568					160		
Ohio	1,423	464,180	22,368	62,123	1,110	63,650	33	4,630	3,630		82
Michigan	1,460	333,950	29,343	197,672	446	12,030	58	9,010	4,125		857
Indiana	32	11,800	753	3,805					279		30
Illinois	10	3,750	645	3,125			3	380	225		90
Wisconsin	299	77,380	18,726	101,641	728	11,366	28	2,435	957		250
Minnesota	1	200	423	4,230					249		
Total	3,750	949,957	101,555	498,096	2,968	96,868	154	17,236	11,614		1,438
Grand total	8,726	2,189,526	244,942	1,728,266	24,180	221,180	5,165	761,286	708,351	561,629	565,833

Products of the fisheries of the Middle Atlantic States.

Species.	New York.		New Jersey.		Pennsylvania.		Delaware.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value	Pounds.	Value.
Alewives	2, 194, 560	$23, 526	1, 978, 055	$14, 286	2, 059, 015	$12, 144	848, 890	$11, 585
Bluefish	5, 506, 575	237, 010	4, 765, 873	178, 691	....	....	....	....
Perch	67, 638	4, 778	571, 347	34, 073	18, 478	811	211, 415	14, 019
Pike	....	....	20, 250	1, 821	5, 481	777	25, 840	1. 604
Sea bass	676, 744	35, 815	3, 892, 311	153, 431	901, 564	37, 555	....	....
Shad	3, 044, 956	161, 209	8, 746, 518	582, 221	1, 996, 482	110, 200	1, 110, 369	60, 255
Spanish mackerel	74, 836	7, 255	117, 254	15, 907	....	....	....	....
Squeteague	2, 531, 523	94, 543	7, 540, 196	208, 051	....	....	837, 510	16, 364
Striped bass	175. 476	18. 207	220, 115	33, 473	23, 352	2, 320	115, 042	15, 442
Oysters	18, 277, 434	2, 748, 509	18, 273, 241	1, 760, 603	926, 660	101, 850	1, 227, 324	73, 863
Clams	6, 030, 020	756, 512	3, 570, 022	381, 841	....	....	21, 360	2. 047
Crabs	529, 066	11, 039	2, 599, 413	50, 278	....	....	1, 164, 675	7, 796
Terrapins	....	....	2, 570	987	....	....	11, 638	2, 136
All others	131, 061, 082	686, 350	18, 949, 426	210, 227	393, 476	18, 374	1, 620, 745	45, 754
Total	170, 169, 910	4, 784, 753	71, 246, 591	3, 625, 890	6, 324, 508	284, 031	7, 194, 808	250, 865

Species.	Maryland.*		Virginia		Total.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
Alewives	17, 418, 850	$131, 245	11, 004, 085	$93, 819	35. 503, 455	$286, 605
Bluefish	516, 364	22. 761	1, 802, 674	66, 004	12, 591. 486	504, 466
Perch	2, 494, 625	105, 078	415, 378	16, 335	3, 778, 881	175, 094
Pike	563, 264	35, 261	9, 450	615	624, 285	40, 078
Sea bass	113, 370	4, 544	9, 440	475	5. 593, 429	231, 820
Shad	6, 224, 873	211. 575	6, 498, 242	207. 394	27. 621, 440	1, 332, 854
Spanish mackerel	44. 837	5, 369	739, 910	50, 756	976, 837	79, 287
Squeteague	750, 465	25, 902	3. 938, 019	124, 891	15, 597, 713	469, 751
Striped bass	1, 264, 693	97, 770	467. 861	40, 953	2, 266, 539	208, 165
Oysters	69, 615, 406	5, 295. 866	43, 061, 452	2, 520, 068	151, 381. 517	12, 500, 759
Clams	147, 760	8, 226	559, 278	36, 030	10, 328, 440	1, 184, 656
Crabs	7, 605, 770	303, 716	2, 890, 427	62, 039	14, 789, 351	434, 868
Terrapins	89, 780	22, 333	52, 215	18, 494	156, 203	43, 950
All others	34, 327, 770	191, 113	112, 504, 126	403, 409	298, 856, 625	1, 555, 227
Total	141, 177, 827	6, 460, 759	183, 952, 557	3, 641, 282	580, 066, 201	19, 047, 580

* Includes District of Columbia.

NOTE.—The numbers of bushels of oysters and clams represented by the weights of the edible parts shown in the table are as follows: Oysters, 2,611,062 bushels in New York, 2,610,463 in New Jersey, 132,380 bushels in Pennsylvania, 175,332 bushels in Delaware, 9,945,058 bushels in Maryland, and 6,151,636 bushels in Virginia. Clams, 716,115 bushels in New York, 443,869 bushels in New Jersey, 2,670 bushels in Delaware, 18,470 bushels in Maryland, and 69,910 bushels in Virginia.

Products of the fisheries of the South Atlantic States.

Species.	North Carolina.		South Carolina.		Georgia.		Florida.		Total.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
Alewives	16, 481, 063	$164, 636	28. 600	$740	24, 000	$580	10, 120	$150	16, 543, 783	$166, 106
Black bass	407, 530	20, 492	2, 100	107	....	....	181, 646	9, 832	591, 276	30, 431
Bluefish	1, 345, 194	33, 603	100, 480	3, 060	....	....	7, 310	255	1, 452, 984	36, 918
Menhaden	12, 410, 400	16, 171	....	....	....	....	....	....	12, 410, 400	16, 171
Mullet	3, 585, 981	97, 408	387, 875	9, 405	52, 740	2, 381	1. 547, 027	24, 441	5, 573, 623	133, 635
Sea bass	33, 075	1, 158	826, 164	26, 283	10, 000	600	10, 445	355	879, 684	28, 396
Shad	5. 768. 413	306, 015	563, 259	41, 187	399, 660	30, 918	2, 654, 022	104, 283	9, 385, 354	482, 403
Squeteague	1, 885, 677	48, 856	103, 106	3, 604	144, 000	7, 911	235, 284	7, 895	2, 368, 067	68, 266
Striped bass	568, 341	32, 138	11, 560	1. 084	9. 000	720	....	....	588, 901	33, 942
Whiting	35, 300	1, 231	523, 520	20, 930	18, 374	1, 060	14, 020	545	591, 214	23, 766
Oysters	5, 650, 820	175, 567	442, 050	23, 204	1, 570, 485	40, 520	681, 450	14, 850	8, 344, 805	254, 141
Shrimps	144, 200	5, 435	371, 840	18, 592	162, 160	6, 081	65, 825	2, 557	744, 025	32, 665
Terrapins	26, 552	4, 690	74, 948	8, 376	43, 050	9, 107	10, 350	1, 425	154, 900	21, 598
Other products	3, 456, 596	120, 269	1, 509, 338	46. 030	560, 648	23, 685	2, 046, 032	69, 472	7, 572, 614	259, 456
Total	51. 799, 142	1, 027, 669	4, 944, 840	202, 602	2, 994, 117	123, 563	7. 463, 531	236, 060	67, 201, 630	1, 589, 894

NOTE.—The quantity of oysters shown is the weight of the edible part. The total number of bushels represented is 1,192,115, of which North Carolina has 807,260, South Carolina 63,150, Georgia 224,355, and Florida 97,350.

Products of the fisheries of the Gulf States.

Species.	Florida.		Alabama.	
	Pounds.	Value.	Pounds.	Value.
Bream and sunfish	38,088	$966	19,200	$960
Catfish			37,600	940
Channel bass	457,737	7,236	54,464	2,242
Croakers	42,923	650	98,075	3,231
Grunts *	680,725	22,202		
Mullet	13,920,962	211,161	587,555	13,097
Pompano	300,356	26,359	17,178	2,577
Sheepshead	543,797	9,449	35,114	1,314
Snappers	4,220,245	124,766	62,375	2,495
Spanish mackerel	440,993	21,100	43,966	2,464
Squeteague	602,463	13,378	208,750	10,706
Sponges	366,772	438,682		
Oysters †	2,597,567	93,692	3,367,490	107,812
Turtles	474,881	21,966		
All other products	2,731,053	112,202	245,201	7,033
Total	27,418,562	1,103,809	4,776,968	154,871

Species.	Mississippi.		Louisiana.	
	Pounds.	Value.	Pounds.	Value.
Bream and sunfish	89,100	$3,609	270,020	$15,682
Buffalo-fish	121,700	1,217	1,180,250	22,940
Catfish	93,400	1,794	2,674,007	54,726
Channel bass	201,300	8,757	339,316	11,270
Croakers	57,325	1,465	158,267	9,479
Mullet	305,400	3,479	287,750	8,021
Pompano	14,875	1,637	32,450	4,378
Sheepshead	173,200	7,870	390,817	25,906
Snappers			240,500	7,215
Spanish mackerel	46,500	3,150	144,000	14,665
Squeteague	372,100	17,596	655,670	33,026
Oysters †	5,645,346	166,672	5,891,095	299,896
Shrimps	613,500	12,622	6,662,050	90,519
Turtles			90,793	2,335
All other products	397,655	15,831	1,772,218	81,226
Total	8,131,401	245,699	20,789,203	681,284

Species.	Texas.		Total.	
	Pounds.	Value.	Pounds.	Value.
Bream and sunfish	34,700	$1,526	451,108	$22,743
Buffalo-fish	13,800	690	1,315,750	24,847
Catfish	45,000	2,090	2,850,007	59,550
Channel bass	1,107,950	47,905	2,160,767	77,410
Croakers	175,950	6,730	532,540	21,555
Grunts			680,725	22,202
Mullet	83,450	2,770	15,185,117	238,528
Pompano	2,000	600	366,859	35,551
Sheepshead	778,800	30,871	1,921,728	75,410
Snappers	4,800	240	4,527,920	134,716
Spanish mackerel	25,000	1,313	700,459	42,692
Squeteague	1,120,450	47,864	2,959,433	122,570
Sponges			366,772	438,682
Oysters †	3,085,600	127,990	20,587,098	796,062
Shrimps	175,800	5,670	7,451,350	108,811
Turtles	583,000	9,345	1,148,674	33,646
All other products	723,100	28,228	5,869,227	244,520
Total	7,959,400	313,832	69,075,534	2,499,495

* In all the States except Florida the catch of grunts has been included with the miscellaneous fish.

† The weight of oysters given in the table represents only the edible part. The equivalent number of bushels in the entire region is 2,941,014, divided as follows among the different States: Florida, 371,081; Alabama, 481,070; Mississippi, 806,478; Louisiana, 841,585; Texas, 440,800.

Products of the fisheries of the Pacific States.

Species.	Alaska.		Washington.		Oregon.		California.		Total.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
Barracuda							654,227	$21,504	654,227	$21,504
Cod	2,259,635	$55,562	794,000	$26,725	26,304	$1,315	2,274,565	56,864	5,354,504	140,466
Flounders			184,560	3,191	10,000	400	4,040,557	85,482	4,235,117	89,073
Halibut			1,903,500	36,560	18,870	1,787	180,930	8,532	2,103,300	46,879
Herring	18,700,000	32,900	542,112	10,567			4,486,887	55,795	23,728,999	99,262
Mackerel							351,961	14,174	351,961	14,174
Perch			65,140	1,303			335,117	10,977	400,257	12,280
Rockfish (*Sebastichthys*)			163,000	4,515	86,115	4,255	1,850,186	52,540	2,099,301	61,310
Salmon	43,199,600	2,212,593	21,684,411	541,546	24,044,151	779,922	4,759,816	176,189	93,687,978	3,710,250
Sardines							752,994	15,237	752,994	15,237
Shad			87,350	2,703	125,000	3,750	526,494	14,372	738,844	20,825
Smelt			321,726	6,158			1,919,894	53,471	2,241,620	59,629
Sturgeon			547,623	5,584	2,513,490	26,399	718,017	21,854	3,779,130	53,837
Yellow-tail							358,954	13,865	358,954	13,865
Octopus and squid							374,622	36,191	374,622	36,191
Terrapins and frogs			13,125	5,250			36,875	8,050	50,000	13,300
Crabs			79,000	3,550	4,125	165	2,862,320	102,900	2,945,445	106,615
Shrimp and prawn			2,000	500			5,315,075	242,161	5,317,075	242,661
Clams and mussels			684,000	5,700	8,250	825	2,969,150	39,108	3,661,400	45,633
Oysters			1,139,803	147,995	17,150	3,062	1,250,515	698,257	2,407,468	849,314
Abalone meat and shells							404,637	9,071	404,637	9,071
Fur seal and other pelts		109,793		121,528		46,526		205,943		483,790
Whale, fish, and seal oil			37,500	1,750			1,578,758	62,295	1,616,258	64,045
Whalebone							198,865	944,609	198,865	944,609
All other products			284,000	9,815			3,608,467	95,290	3,892,467	105,105
Total	64,159,235	2,410,848	28,532,850	934,940	26,853,455	868,406	41,809,883	3,044,731	161,355,423	7,258,925

NOTE.—The numbers of bushels of oysters, clams, and mussels represented by the weights shown in the table are as follows: Oysters, 178,645 bushels in California, 2,450 bushels in Oregon, 162,829 bushels in Washington. Clams, 40,470 bushels in California, 825 bushels in Oregon, 11,400 bushels in Washington. Mussels, 10,000 bushels in California.

The number of skins of seals, sea otters, and other mammals, the value of which are given, are as follows: Fur seals, 14,710 in California, 2,945 in Oregon, 9,143 in Washington, 7,175 in Alaska. Sea otters, 235 in California, 20 in Oregon, 18 in Alaska. Hair seals and sea lions, 952 in California.

Products of the fisheries of the Great Lakes.

Species.	New York.		Pennsylvania.		Ohio.		Michigan		Indiana.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
Bass	48,797	$3,187	19,990	$1,032	203,223	$11,096	97,987	$5,109	5,393	$270
Herring	2,406,098	49,367	8,012,510	80,443	27,888,653	281,878	6,393,756	87,437	160,408	3,206
Perch	407,567	6,883	208,540	5.420	2,483,247	22,189	3,029,464	40,380	106,064	3,184
Pike and pike perch	819,519	49,723	3,402,285	76,436	9,442,291	185,061	2,689,891	86,677		
Sturgeon	2,251,416	82,968	105,750	3,265	230,493	8,861	1.480,256	45.073	70,716	2,780
Trout	80,430	3,992	82,000	3,280			8,542,952	309,616	154,733	7,730
Whitefish	466,621	22,610	758,019	36,157	1,129,582	57,278	7,725,105	312,411	66,901	2.951
Others	1,607,521	37,776	275,750	5,089	3,554,619	52.320	2,012,578	47,302	75,278	1,572
Total	8,087,969	256,506	12,864,844	211,122	44,932,108	618,683	32,871,989	934,005	639,493	21,693

Species.	Illinois.		Wisconsin.		Minnesota.		Total.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
Bass			87,696	$4,379			463,086	$25,073
Herring	88,375	$1.768	3,798,220	57.502	5,329	$102	48,753,349	561,703
Perch	511,909	14.009	1,008,137	21,195			7,754,028	113,260
Pike and pike perch			481,118	19,141			16,835,119	417,038
Sturgeon	16,480	640	134,648	4,779			4,289,759	148,366
Trout	71,660	3.479	3.820,178	175,334	138,488	4.519	12,890,441	507,950
Whitefish	27,835	1,400	2.187,667	84.467	39,605	1,617	12,401,335	518,891
Others	107,035	2,540	1,978,633	32,888			10,511,414	179,487
Total	822,394	23.836	13,496.312	399,685	183.422	6,238	113.898,531	2,471,768

The products classified.—In the following table the value of the fishing industry ni each State is shown for eight main branches into which the products may be naturally divided. These are (1) the general fisheries for food and bait fishes; (2) the menhaden fishery for oil and guano factories; (3) the fisheries for oysters, clams, scallops, squid, octopus, and other mollusks; (4) the crab, lobster, shrimp, and other crustacean fisheries; (5) the alligator, terrapin, turtle, and other reptilian fisheries; (6) the fisheries for whales, porpoises, and other cetaceans; (7) the seal and sea-otter fisheries, and (8) the sponge fishery.

Fishes proper, excluding menhaden, have a value of $21,243,000, or nearly as much as the combined value of all other classes of products. Mollusks are worth over $18,100,000. The products of the whale and porpoise fisheries have a value of about $2,146,000. Closely following the cetaceans are the crustaceans, with a value of $2,028,000. The menhaden fishery yields $638,668, a sum representing the value of the fresh fish and not that of the manufactured products. The seal and the sea-otter fisheries, worth $502,180, occupy the next position. The sponge fishery and the reptilian fisheries, which complete the list, have a valuation of $438,682 and $215,000, respectively.

The States which lead in the different branches are as follows: Massachusetts in the food and bait fisheries and in the whale fishery; Maryland in the molluscan fisheries; Maine in the crustacean fisheries; California in the seal and sea-otter fisheries; New York in the menhaden fisheries and Florida in the reptilian and sponge fisheries. The killing of an ordinary number of seals on the Pribilof Islands would place Alaska at the head of that group, but in the year covered by the figures the seal catch was reduced by law to about 7,500 skins.

Table showing by States and fisheries the value of the fisheries of the United States.

States.	General food-fish and bait fisheries.	Menhaden fishery.	Molluscan fisheries.	Crustacean fisheries.	Reptilian fisheries.	Whale fisheries.	Seal and sea-otter fisheries.	Sponge fishery.	Total.
Alabama	$46, 119		$107, 812		$940				$154, 871
Alaska	2, 301, 055						$109, 793		2, 410, 848
California	687, 902		782, 627	$353, 547	8, 050	$1, 006, 662	205, 943		3, 044, 731
Connecticut	244, 925	$28, 622	1, 476, 435	101, 318		1, 723	18, 390		1, 871, 413
Delaware	163, 443		75, 910	8, 081	3, 431				250, 865
Florida	702, 090		109, 649	2, 742	86, 706			$438, 682	1, 339, 869
Georgia	66, 495		40, 820	7, 141	9, 107				123, 563
Illinois	23, 836								23, 836
Indiana	21, 693								21, 693
Louisiana	239, 449		299, 896	116, 911	25, 028				681, 284
Maine	1, 410, 428		165, 487	649, 891					2, 225, 806
Maryland *	765, 199	60, 533	5, 304, 092	308, 371	22, 564				6, 460, 759
Massachusetts	5, 848, 932		343, 171	206, 338		1, 132, 753			7, 531, 194
Michigan	933, 005				1, 000				934, 005
Minnesota	6, 238								6, 238
Mississippi	64, 368		166, 672	14. 659					245, 699
New Hampshire	77, 364		975	13, 142					91, 481
New Jersey	1, 393, 151	27, 609	2, 142, 444	61, 639	1, 047				3, 625, 890
New York	1, 153, 189	291, 165	3, 570, 211	26, 694					5, 041, 259
North Carolina	806, 560	15, 920	188, 457	6, 620	5, 714	4, 398			1, 027, 669
Ohio	615, 609				3, 074				618, 683
Oregon	817, 828		3, 887	165			46, 526		868, 406
Pennsylvania	393, 303		101, 850						495, 153
Rhode Island	283, 926	28, 771	359, 216	53, 762					725, 675
South Carolina	150, 690		23, 204	20, 332	8, 376				202, 602
Texas	164, 200		127, 990	10, 765	10, 877				313, 832
Virginia	812, 870	186, 048	2, 556, 098	62, 114	24, 152				3, 641, 282
Washington	649, 817		153, 695	4, 050	5, 250	600	121, 528		934, 940
Wisconsin	399, 272								399, 272
Total	21, 242, 956	638, 668	18, 100, 598	2, 028, 282	215, 316	2, 146, 136	502, 180	438, 682	45, 312, 818

* Includes District of Columbia.

Rank and value of principal fishery products.—The principal fisheries have in the following table been arranged in four groups based on the value of the catch. Sixty fisheries or special products have an annual valuation of over $35,000. Nine of these are worth more than $1,000,000; 9 between $500,000 and $1,000,000; 25 between $100,000 and $500,000, and 17 between $35,000 and $100,000.

The 9 fisheries which yield over $1,000,000 represent nearly three-fourths of the total output of the United States fisheries. They include 4 fisheries prosecuted on both the Atlantic and Pacific coasts, 4 that are peculiar to the Atlantic seaboard, and 1 that is confined to the west coast. The chief among them, the oyster, is worth over $16,000,000, or more than one-third the value of the entire industry. The Pacific salmon fishery ranks second; it is worth about $3,700,000. The Atlantic cod fishery and the whale fishery have a valuation of over $2,000,000. The other fisheries in this group are the shad, clam, mackerel, lobster, and haddock.

The leading product in the second class is the halibut, valued at about $874,000. Five other products included in this group are marine or coast animals, viz, squeteague, menhaden, bluefish, alewives, and crabs, and the remaining three belong in the Great Lakes, viz, the herring or cisco, the whitefish, and the lake trout.

Of the 25 products having a value between $100,000 and $500,000, the sponges head the list. In this division are found such well-known fisheries as the fur-seal, shrimp, mullet, hake, sea bass, herring, sturgeon, striped bass, eel, scup, snapper, Spanish mackerel, smelt, sheepshead, channel bass, pike perch, scallop, etc.

The fourth group embraces most of the remaining fisheries of general or local importance. Among the fisheries now having a valuation of less than $100,000 and more than $35,000 are the herring, rockfish, smelt, and sea-otter fisheries of the Pacific coast; and the pollock, swordfish, tautog, pike, and black bass fisheries of the east coast.

Table showing rank and value of the 60 most important fisheries or special products of the United States.

Rank.	Fisheries.	Value.
	I. Over $1,000,000.	
1	Oyster	$16,152,257
2	Pacific salmon	3,710,250
3	Atlantic cod	2,856,225
4	Whale	2,141,738
5	Shad	1,879,688
6	Clam	1,690,536
7	Mackerel	1,102,651
8	Lobster	1,050,677
9	Haddock	1,045,814
	II. From $500,000 to $1,000,000.	
10	Halibut	873,910
11	Squeteague	708,830
12	Menhaden	693,808
13	Bluefish	637,305
14	Crab	572,147
15	Lake herring	561,703
16	Alewife	554,740
17	Lake whitefish	518,891
18	Lake trout	507,950
	III. From $100,000 to $500,000.	
19	Sponge	438,682
20	Pike perch and pike (Great Lakes)*	417,038
21	Fur-seal	396,627
22	Shrimp and prawn	389,297
23	Mullet	387,916
24	Hake	367,636
25	Sea bass	356,803
26	Atlantic herring	329,298
27	Sturgeon	271,328
28	Striped bass or rockfish	259,474
29	Eel	255,801
	III. From $100,000 to $500,000—Continued.	
30	Flatfish	$249,095
31	Scup	205,421
32	Atlantic yellow and white perch*	197,863
33	Catfish	178,758
34	Scallop	172,963
35	Red snapper	147,744
36	Pacific cod	140,466
37	Cusk	136,215
38	Spanish mackerel	129,250
39	Spot and croaker	128,852
40	Atlantic smelt	122,115
41	Yellow perch (Great Lakes)	113,260
42	Sheepshead	101,925
43	Channel bass or redfish	100,386
	IV. From $35,000 to $100,000.	
44	Pacific herring	99,262
45	Pollock	90,169
46	Alligator	77,010
47	Terrapin	76,243
48	Sunfish	72,130
49	Algæ	69,231
50	Pacific rockfish	61,310
51	Pacific smelt	59,629
52	Swordfish	56,525
53	Butterfish	50,765
54	Tautog	47,900
55	Pompano	47,631
56	Turtle	47,475
57	Atlantic pike	43,328
58	Octopus and squid	40,691
59	Black bass	38,969
60	Sea otter	38,370

* Species can not be satisfactorily separated.

Statistics of special important products.—To facilitate the comprehension of the extent of some of the principal fisheries prosecuted in the coast States, the following tables, based on preceding ones, are presented. They relate to the catch of oysters, whales, lobsters, crabs, clams, shad, alewives, bluefish, and squeteague.

The oyster, the foremost water product in the United States, is the object of a commercial fishery in every coast State except Maine and New Hampshire. In 12 States—viz, Alabama, Connecticut, Delaware, Georgia, Louisiana, Maryland, Mississippi, New Jersey, New York, Rhode Island, Texas, and Virginia—it is the most valuable fishery product taken. In each of 5 States—Connecticut, Maryland, New Jersey, New York, and Virginia—its annual value is over $1,000,000. The output of the entire country is about 28,000,000 bushels, whose value to the fishermen is $16,152,000. No other object of our fisheries has received so much attention as the oyster and is so generally cultivated by private individuals. Statistics of the oyster catch in each State are shown in the following table:

The oyster output of the United States.

States.	Bushels.	Value.
Alabama	481,070	$107,812
California	178,645	698,257
Connecticut	1,950,174	1,426,249
Delaware	175,332	73,863
Florida	468,431	108,542
Georgia	224,355	40,520
Louisiana	841,585	299,896
Maryland	9,945,058	5,295,866
Massachusetts	52,608	70,240
Mississippi	806,478	166,672
New Jersey	2,610,463	1,760,603
New York	2,611,062	2,748,509
North Carolina	807,260	175,567
Oregon	2,450	3,062
Pennsylvania	132,380	101,850
Rhode Island	158,081	255,492
South Carolina	63,150	23,204
Texas	440,800	127,990
Virginia	6,151,636	2,520,068
Washington	162,829	147,995
Total	28,263,847	16,152,257

The pursuit of whales and porpoises is a commercial enterprise in 5 States, but is comparatively unimportant in 3 of them. It is only in Massachusetts and California that whaling is a conspicuous feature of the fisheries. The table shows that the California whale fishery yielded a return of $1,006,662 and that of Massachusetts $1,132,753. While a large part of the Massachusetts whaling fleet make their headquarters at San Francisco and cruise in the Pacific Ocean, the catch of the vessels has been credited to Massachusetts, the California figures representing only the yield of the vessels owned in that State.

Statistics of the products of the whale fishery of the United States.

States.	Whalebone.		Oil.		Ambergris.		Porpoises.	
	Pounds.	Value.	Gallons.	Value.	Pounds.	Value.	No.	Value.
California	198,865	$944,609	205,699	$62,053				
Connecticut	150	400	3,150	1,323				
Massachusetts	149,838	748,825	656,298	378,650	$20\frac{1}{32}$	$5,278		
North Carolina							1,747	$4,398
Washington				*600				
Total	348,853	1,693,834	865,147	442,626	$20\frac{1}{32}$	5,278	1,747	4,398

* Value of whales used by Indians for food.

In the 8 States of the Atlantic seaboard north of Maryland lobster fishing is carried on. The abundance of that crustacean increases from south to north, and the most southern and most northern States in which it is sought have, respectively, the minimum and maximum output. The catch in Maine, amounting to over 17,000,000 pounds, worth $650,000, is more important than any other product of the fisheries, and in Connecticut, where the yield is 1,615,000 pounds, valued at $101,000, it is surpassed only by the oyster. The aggregate product is 23,301,149 pounds, with a value of $1,041,677, divided as follows among the different States:

Output of the lobster fishery of the United States.

States.	Pounds.	Value.
Connecticut	1, 614, 530	$101, 318
Delaware	8, 200	410
Maine	17, 198, 002	649, 891
Massachusetts	3, 177, 295	205, 638
New Hampshire	220, 024	13, 142
New Jersey	143, 905	10, 861
New York	165, 093	15, 655
Rhode Island	774, 100	53, 762
Total	23, 301, 149	1, 050, 677

Several species of crabs are of commercial value in 15 States of the Atlantic, Gulf, and Pacific regions. They are actually and relatively most important in Maryland, where the reported yield is over 7,600,000 pounds, valued at $303,700. Crabs there rank next to oysters in value. Other States having a crab fishery of considerable magnitude are California, Virginia, New Jersey, and Delaware, in which the yield is between 1,000,000 and 3,000,000 pounds, as the following table indicates:

The crab catch of the United States.

States.	Pounds.	Value.
California	2, 862, 320	$102, 900
Delaware	1, 164, 675	7, 796
Florida	4, 100	185
Georgia	47, 866	1, 060
Louisiana	980, 700	19, 362
Maryland	7, 605, 770	303, 716
Mississippi	47, 160	2, 037
New Jersey	2, 599, 413	50, 278
New York	529, 066	11, 039
North Carolina	47, 400	1, 185
Oregon	4, 125	165
South Carolina	93, 260	1, 740
Texas	190, 800	5, 095
Virginia	2. 890, 427	62, 039
Washington	79, 000	3, 550
Total	19, 146, 082	572, 147

Clams of several kinds exist as economic objects in 16 States. They are especially prominent in the fisheries of Maine, Massachusetts, New York, and New Jersey, in which the aggregate output is 1,860,000 bushels, valued at $1,487,000, the production in the entire country being 2,129,373 bushels, worth $1,690,536. The yield in each State is as follows:

Statistics of the products of the clam fishery of the United States.

States.	Bushels.	Value.
California	40, 470	$27, 108
Connecticut	40, 800	43, 656
Delaware	2, 670	2, 047
Florida	1, 433	1, 097
Georgia	500	300
Maine	454, 501	156, 033
Maryland	18, 470	8, 226
Massachusetts	245, 291	192, 724
New Hampshire	1, 050	975
New Jersey	443, 869	381, 841
New York	716, 115	756, 512
North Carolina	28, 269	12, 090
Oregon	825	825
Rhode Island	53, 800	65, 372
Virginia	69, 910	36, 030
Washington	11, 400	5, 700
Total	2, 129, 373	1, 690, 536

The shad is the most valuable anadromous fish of the Atlantic coast and one of the most generally distributed food species. As shown by the following table, it is the object of commercial fishing in all coast States except New Hampshire and those bordering on the Gulf of Mexico. Even in the gulf region it occurs sparingly in several States, where it has been artificially introduced, but it does not exist there in sufficient abundance to constitute an economic commodity. In Pennsylvania, North Carolina, and South Carolina it is the principal product of the fisheries, and in New Jersey, Delaware, Virginia, and Georgia it is surpassed only by the oyster. The fishery is most extensive in New Jersey, where the accredited catch is about 8,747,000 pounds, valued at $582,000. Two of the best shad rivers in the country mark the boundaries of this State, and in them and their estuaries extensive fishing is carried on. Virginia, Maryland, North Carolina, New York, Florida, Pennsylvania, and Delaware follow New Jersey in the order named as regards the quantity of the catch, the output ranging from 1,110,000 pounds in Delaware to 6,498,000 pounds in Virginia. The value of the yield, however, is greater in North Carolina than in any other State save New Jersey, the rank of the other States in this respect being Maryland, Virginia, New York, Pennsylvania, Florida, and Delaware.

The shad catch of the United States.

States.	Pounds.	Value.
California	526, 494	$14, 372
Connecticut	105, 109	8, 988
Delaware	1, 110, 369	60, 255
Florida	2, 654, 022	104, 283
Georgia	399, 660	30, 918
Maine	815, 620	28, 121
Maryland	6, 224, 873	211, 575
Massachusetts	140, 260	5, 721
New Jersey	8, 746, 518	582, 221
New York	3, 044, 956	161, 209
North Carolina	5, 768, 413	306, 015
Oregon	125, 000	3, 750
Pennsylvania	1, 996, 482	110, 200
Rhode Island	24, 350	776
South Carolina	563, 259	41, 187
Virginia	6, 498, 242	207, 394
Washington	87, 350	2, 703
Total	38, 830, 977	1, 879, 688

Similar to the shad in distribution are the alewives, or river herrings. They are taken in largest quantities in Maryland, Virginia, and North Carolina, in which States the catch is, respectively, about as follows: Maryland, 17,418,000; Virginia, 11,000,000, and North Carolina, 16,481,000. They are also of considerable economic importance in Massachusetts, New York, New Jersey, and Pennsylvania, in each of which the output is about 2,000,000 pounds or over. The quantity and value of the yield in each State is as follows:

The alewife catch of the United States.

States.	Pounds.	Value.
Connecticut	679, 120	$3, 808
Delaware	848, 890	11, 585
Florida	10, 120	150
Georgia	24, 000	580
Maine	2, 113, 950	19, 104
Maryland	17, 418, 850	131, 245
Massachusetts	3, 326, 445	60, 056
New Hampshire	41, 500	770
New Jersey	1, 978, 055	14, 286
New York	2, 194, 560	23, 526
North Carolina	16, 481, 063	164, 636
Pennsylvania	2, 059, 015	12, 144
Rhode Island	967, 930	18, 291
South Carolina	28, 600	740
Virginia	11, 004, 085	93, 819
Total	59, 176, 183	554, 740

The catch of weakfish and of spotted squeteague has, in the following table, been combined. The aggregate yield is 22,340,000 pounds, having a first value of $708,830. The fish are obtained in 16 States, and in some of them occupy a prominent position in the list of fishery products. More than one third the catch in the entire country is taken in New Jersey, where the weakfish ranks next to the shad in importance. In Virginia, New York, North Carolina, and Texas the yield is very large.

The squeteague catch of the United States.

States.	Pounds.	Value.
Alabama	208, 750	$10, 706
Connecticut	285, 310	11, 290
Delaware	837, 510	16, 364
Florida	837, 747	21, 273
Georgia	144, 000	7, 911
Louisiana	655. 670	33, 026
Maryland	750, 465	25, 902
Massachusetts	240, 000	7, 200
Mississippi	372, 100	17, 596
New Jersey	7, 540, 196	208, 051
New York	2, 531, 523	94, 543
North Carolina	1, 885, 677	48, 856
Rhode Island	889, 910	29, 753
South Carolina	103, 106	3, 604
Texas	1, 120, 450	47, 864
Virginia	3, 938, 019	124, 891
Total	22, 340, 433	708. 830

The bluefish is one of the most generally distributed, best-known, and important fishes found on the east coast of the United States. The following table shows a catch of nearly 16,000,000 pounds, with a value to the fishermen of $637,000. About two-thirds of the output is taken in New York and New Jersey; in the former State the bluefish is more important than any other fish, and is surpassed in value only by the oyster and clam. Virginia and North Carolina have a relatively large catch of this fish, the quantity taken in each being between one and two million pounds.

The bluefish catch of the United States.

States.	Pounds.	Value.
Alabama	55, 760	$1, 213
Connecticut	640, 450	32, 022
Florida	7, 310	255
Louisiana	13, 050	843
Maryland	516, 364	22, 761
Massachusetts	415, 560	31, 167
Mississippi	95, 900	4, 595
New Jersey	4, 765, 873	178, 691
New York	5, 506, 575	237, 010
North Carolina	1, 345, 194	33, 603
Rhode Island	247, 100	14, 356
South Carolina	100, 480	3, 060
Texas	25, 500	1, 327
Virginia	1, 802, 674	66, 004
Total	15, 957, 836	637, 305

The catch by different forms of apparatus.—In the accompanying table the quantity and value of the products resulting from the use of the different kinds of apparatus are shown for each State, the catch with each of the following forms being separately given, viz, (1) purse seines; (2) haul and other seines; (3) gill nets and trammel nets; (4) pound nets, trap nets, and weirs; (5) fyke nets and pots; (6) lines; and (7) dredges, tongs, and rakes.

Excluding the oysters, clams, and other mollusks, taken with dredges, tongs, etc., the value of which, $18,269,465, is much greater than the yield of any other class of appliances, it appears that lines are the most important form of apparatus employed in the capture of fish proper. While the quantity of fish thus obtained is less than with purse seines, the value of the catch is much greater, being about $7,220,000. Gill nets and trammel nets rank second in value of yield, which is about $4,888,000. Haul seines take products worth nearly as much as those obtained with gill nets, viz, $4,061,000. Pound nets, trap nets, and weirs have an output valued at $3,412,000. Fyke nets and the closely related pots rank next in the value of the catch, which is worth about $1,504,000. Closely following are purse seines, whose yield is valued at $1,409,000.

The States in which the purse seine is most valuable as a productive agent are Massachusetts, where it is employed in the capture of mackerel, and New York, where the fishery is for menhaden. The haul seine is far more important in Alaska than elsewhere, salmon being the principal object of fishery. The State holding the next position as regards the extent of its haul-seine fishery is North Carolina, where large quantities of shad and alewives are thus taken. The gill net is also more productive in the salmon fishery of Alaska than elsewhere, and is next important in the shad fishery of New Jersey. The use of the pound-net type of apparatus is most important in Virginia and Michigan. Maine and Massachusetts lead in the value of their combined fyke and pot fisheries, the lobster constituting the principal object taken. The value of the fyke catch alone is greatest in New York. The results of line fishing are far greater in Massachusetts than in all other States taken together; lines, in this State, are more prominent than any other form of apparatus in any other State except dredges and tongs in the oyster fishery of Maryland. Maine follows Massachusetts in the value of its line fishing.

Table showing by States the quantity and value of the products taken with each principal form of apparatus.

States.	Purse seines.		Haul and other seines.		Gill nets and trammel nets.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
Alabama			770,053	$24,190	510,300	$18,762
Alaska	600,000	$34,650	42,461,000	1,301,010	16,174,320	772,921
California	357,622	35,762	*16,683,006	476,807	9,220,198	274,950
Connecticut	10,222,300	29,219	221,051	8,004	727,496	11,217
Delaware			1,671,633	44,918	2,697,624	102,936
Florida			8,390,444	204,490	15,197,223	278,185
Georgia			67,230	10,363	608,662	37,063
Illinois			34,365	856	220,645	7,208
Indiana					314,467	10,421
Louisiana			10,300,553	240,663		
Maine	1,630,230	110,061	4,656,345	83,983	9,167,537	142,540
Maryland	28,816,000	60,533	14,320,173	366,609	8,571,287	217,088
Massachusetts	9,012,280	559,742	4,053,640	55,020	4,542,305	142,605
Michigan			848,735	19,678	12,085,678	408,943
Minnesota					150,465	5,261
Mississippi			2,231,205	68,736	220,750	9,185
New Hampshire	42,000	3,705	16,000	430	146,000	1,080
New Jersey	8,571,900	27,609	8,306,067	165,234	9,083,306	572,900
New York	80,057,980	288,123	4,245,731	161,710	9,924,736	370,105
North Carolina	12,200,400	15,920	18,171,082	411,346	6,354,178	252,249
Ohio			600,700	15,535	13,530,618	193,523
Oregon			1,558,302	46,119	5,004,295	124,956
Pennsylvania			3,104,388	82,913	12,713,135	226,105
Rhode Island	5,342,100	28,916	660,760	17,170	233,160	13,141
South Carolina			702,853	29,370	788,730	42,474
Texas			3,784,100	157,422		
Virginia	100,085,700	136,348	4,150,252	97,483	4,867,014	124,463
Washington	2,822,191	27,603	3,261,352	62,631	9,143,086	274,698
Wisconsin			400,873	8,900	7,513,323	241,185
Total	279,430,473	1,406,791	155,540,851	4,661,480	180,744,578	4,877,834

States.	Pound nets, trap nets, and weirs.		Fyke nets and pots.		Lines.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
Alabama					86,625	$2,086
Alaska	2,004,280	$136,912			2,250,635	55,582
California			480,722	$15,656	5,006,402	167,980
Connecticut	5,380,886	52,369	2,119,800	124,855	3,630,835	106,315
Delaware	444,919	1,129	158,675	7,207	52,700	2,635
Florida	86,715	1,985			6,083,996	211,798
Georgia	42,805	1,285	20,180	806	401,136	16,967
Illinois	41,730	1,300			850,843	10,582
Indiana	250,772	7,985			58,600	2,008
Louisiana					3,325,176	81,867
Maine	88,788,072	306,871	17,802,562	656,200	83,826,330	732,900
Maryland	8,877,000	165,550	2,945,650	77,649	3,506,084	70,388
Massachusetts	75,784,900	408,780	5,577,400	226,875	140,852,736	4,482,900
Michigan	37,126,807	452,862	1,805,624	51,271	916,365	29,734
Minnesota	10,530	296			22,457	679
Mississippi					19,400	836
New Hampshire	46,100	852	220,024	75,142	3,444,750	86,300
New Jersey	16,864,000	195,000	925,870	46,855	16,877,843	438,482
New York	22,294,296	182,136	4,422,279	146,829	6,906,892	571,004
North Carolina	8,286,562	136,906	179,300	5,896	465,775	14,546
Ohio	27,582,045	345,142	2,384,945	46,573	514,900	21,089
Oregon	4,852,805	152,365			2,596,406	22,900
Pennsylvania	1,214,848	26,006	156,800	7,132	1,082,863	46,300
Rhode Island	17,136,010	196,100	902,075	56,887	986,105	44,438
South Carolina					2,567,308	82,225
Texas					302,400	6,305
Virginia	34,065,367	476,294	825,062	15,406	5,865,129	136,300
Washington	6,082,967	154,102			5,534,301	82,215
Wisconsin	2,006,006	102,340	1,827,345	26,307	496,296	16,809
Total	397,456,367	3,422,622	[illegible]	1,544,045	[illegible]	[illegible]

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* Includes the catch with bag nets.

Table showing the quantity and value of products taken with each principal form of apparatus—Continued.

States.	Dredges, tongs, rakes, etc.		All other apparatus.		Total.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
Alabama	3,367,490	$107,812	40.500	$1.012	4.776.968	$154,871
Alaska				109.793	64.159,235	2,410,848
California	4,219,665	737,365	5,232.269	1,338.260	41,809,833	3.044,731
Connecticut	25,426,518	1,476,435	15,849,745	43.021	61,458,221	1.871.413
Delaware	1,248,684	75.910	925.513	16,140	7.194.808	250,865
Florida	3,291,947	109.639	1.231.848	534,397	34,882.093	1.339.869
Georgia	1.574,485	40.820	280.717	14,187	2.994,117	123.563
Illinois			175,421	3.781	822,394	23,836
Indiana			14.866	681	639.493	21,693
Louisiana	5,891,095	299,896	1.382,379	58,918	20,789,203	681,284
Maine	4.661,135	165,487	16.580,040	91,575	121,700.200	2,225,806
Maryland	72.869,251	5,498,770	2,213.763	104,248	141,177.827	6,460,759
Massachusetts	3,379,315	338.671	111.702,855	1.335,994	301,349,331	7,531.194
Michigan			283,800	10,597	32.871,989	934,005
Minnesota					183,422	6,238
Mississippi	5.645,346	166,672	14.500	290	8.131.201	245,699
New Hampshire	10.500	975	37.450	2,537	3,956,824	91.481
New Jersey	21,961,496	2,146.819	608,020	51.283	71.246.591	3,625,890
New York	41,407,596	3,570,211	1,018.841	51.449	178,257,879	5,041,259
North Carolina	5,894,972	188,457	258,873	11.245	51,799,142	1,027,669
Ohio				2.500	44.932,108	618,683
Oregon	25.400	3.887	12.798.007	505,492	26,853,455	868.406
Pennsylvania	926,660	101,850	39,579	2.726	19,189.352	495,153
Rhode Island	1,976.035	359,216	172,480	7.762	21,434,665	725,675
South Carolina	442,050	23.204	464,904	26,329	4,944,840	202,602
Texas	3,085.600	127,990	887,300	19,825	7,959,400	313,832
Virginia	44,011,368	2,575.684	269,066	31,053	183,952,557	3.641,282
Washington	1,823,803	153.695	2,085,951	180,957	28,532,850	934,940
Wisconsin			43,748	2.187	13,474,583	399,272
Total	253,140.411	18,269,465	174,612,435	4.558,239	1,501,474,631	45.312,818

Shore fishery industries.—Among the most important industries directly connected with the fisheries are sardine canning, the manufacture of menhaden oil and guano, salmon canning, oyster packing and canning, and the canning of various other fishery products, as mackerel, clams, turtles, and shrimp. These give employment to over 30,000 people; represent an investment of over $14,000,000; utilize 530,000,000 pounds of raw materials, for which $10,458,000 is paid; and produce manufactured articles having a value of $20,548,000. The canning of sardines and the canning of mackerel and clams are usually done by the same firms, so that it is not feasible to present separate figures for each of these branches. Lobsters are also canned principally at sardine factories, but owing to the importance of this industry, an effort has been made to represent it separately as regards the employés and investment. The packing and canning of oysters constitute the most important of the industries exhibited in the table, after which come salmon canning, sardine canning, and the manufacture of oil and fertilizer from menhaden.

Table showing the extent of some of the principal shore fishery-industries of the United States.

Industries.	Number of establishments	Number of shore employés.	Value of plants.	Cash capital.	Raw products utilized.		Value of products prepared.
					Pounds.	Value.	
Sardine, mackerel, and clam canning	57	4,754	$358,200	$508,100	46,548,595	$231,529	$2,232,736
Lobster canning	11	307	24,200	38,500	5,326,322	78,720	197,574
Menhaden	50	1,431	900,300	743,000	288,764,767	650,802	1,142,998
Oyster packing and canning	301	17,733	3,247,866	2,835,300	99,177,680	6,763,160	10,145,827
Salmon canning	93	5,374	2,086,947	3,413,350	89,035,455	2,684,107	6,706,774
Shrimp canning	6	430	35,500	41,000	1,653,246	44,999	109,304
Turtle canning	1	10	7,000	6,000	243,000	4,455	12,900
Total	519	30,039	6,660,013	7,585,250	530,749,065	10,457,772	20,548,113

UNITED STATES FISHERIES COMPARED WITH THOSE OF OTHER COUNTRIES.

As a matter of general interest, the following comparison between the fisheries of the United States and those of other countries is presented. The figures for the foreign countries are the most authentic and recent ones available, have been obtained largely from the latest official records, and represent the value of the products taken. Unfortunately, it is not possible to exhibit figures for a number of countries having commercial fisheries, owing to the fact that there are no published reports available relating to the subject; among these are China, India, Germany, Austria, Denmark, Belgium, Turkey, Greece, Mexico, and Australia.

The prominent position occupied by the United States in the matter of fisheries will doubtless occasion some surprise. It is far in advance of any other country, surpassing Great Britain, the next important country, by over $10,000,000.

The table shows the value of the fisheries of most of the principal countries of the world. As a matter of additional interest, columns are inserted showing the population of each and the average amount of money resulting from the fisheries for each inhabitant. A comparison of this kind would be much more valuable if it could include other items besides the value of the catch, as, for example, the number of persons employed, the number of vessels and boats engaged, the quantity of apparatus used, and the amount of capital invested; but such information is at hand for only a few countries. It appears that in proportion to the population Newfoundland has more important fisheries than any other country; the average value of the catch per inhabitant is $33.82, while in the United States it is only 70 cents. Other countries having a greater relative catch than the United States in proportion to population are Great Britain, Norway, and Portugal.

Countries.	Approximate population.	Approximate value of fisheries.	Average value of catch per inhabitant.
United States	65,000,000	$45,223,000	$0.70
Great Britain	35,300,000	32,000,000	.91
Japan	40,072,000	26,000,000	.65
Russia	87,850,490	22,000,000	.25
France	38,343,200	21,256,300	.55
Canada	4,833,500	18,977,900	3.93
Norway	1,999,200	8,000,000	4.00
Newfoundland	197,500	6,679,600	33.82
Portugal	4,306,550	3,400,000	.79
Spain	17,266,100	2,500,000	.14
Holland	4,564,600	2,225,000	.49
Sweden	4,579,100	2,300,000	.50
Italy	28,459,600	1,216,000	.04

COMPARISONS WITH 1880.

Perhaps the most valuable purpose which statistics subserve is the opportunity they afford for making comparisons from time to time between the present and past condition of an industry. In the case of the fisheries this comparison must determine the necessity for legal restriction of certain fisheries, the desirability of undertaking artificial propagation, and the results of restriction and cultivation, besides indicating the actual and relative extent of the industry.

It is not the purpose to discuss all the details of comparison between the present status of the fishing industry and its condition in 1880, but simply to direct attention to the general features of the variations that have occurred and to notice certain specially striking changes in the condition of our fisheries.

Considering the persons employed in various capacities in the fishing industry, the statistics show an increase over 1880 amounting to about 51,000 persons. The principal increase, aggregating 30,832 persons, occurred in the Middle Atlantic States, although all the other geographical sections, except New England and the Pacific coast, show a substantial gain. The decrease in New England is only 18 persons, and that in the Pacific States is also insignificant, being only 32.

The amount of capital invested in the fishing industry is at present much larger than in 1880, the increase amounting to about $20,285,000. This is due largely to the employment of improved types of vessels, the use of greater quantities of the most modern and expensive forms of apparatus, and the building of new factories, canneries, and other shore establishments directly connected with the fisheries. A larger investment is to be observed in every region, except the New England States, where there has been a diminution amounting to about $78,000. In the Middle Atlantic region the increased investment is $6,720,000, while in the Pacific States, with a relatively small investment, the augmentation in the capital devoted to the industry is $6,125,000.

Comparing the present value of the products of the United States fisheries with their value in 1880, an advance is to be noted, which, while not relatively so large as the increase in the fishing population and the invested capital, is, perhaps, not discouraging, in view of the recent scarcity of three of the most important objects of fishery in 1880, viz, mackerel, fur seals, and whales. The increased value of the yield amounts to about $6,630,000. The fisheries of New England have decreased in value to the extent of $64,000, while every other region presents an increase, varying from $333,000 in the South Atlantic States to $2,687,000 in the Middle Atlantic States.

The following table shows the extent of the fisheries of the United States in 1880 and at the present time, together with the number of persons employed, the amount of capital invested, and the value of the catch in each State and each geographical region:

Comparative summary of the fisheries of the United States in 1880 and 1892.

States.	Persons employed.		Capital invested.		Value of products.	
	1880.	1892.[*]	1880.	1892.	1880.	1892.
New England:						
Maine	11,071	15,128	$3,375,994	$2,882,113	$2,742,571	$2,225,806
New Hampshire	414	373	209,465	93,328	176,684	91,481
Massachusetts	20,117	17,025	14,334,450	12,980,679	7,959,760	7,531,194
Rhode Island	2,310	1,584	596,678	1,034,467	696,814	725,675
Connecticut	3,131	2,915	1,421,020	2,868,921	933,242	1,871,413
Total	37,043	37,025	19,937,607	19,859,508	12,509,071	12,445,569
Middle Atlantic:						
New York	6,344	12,246	2,573,535	5,282,970	3,763,537	4,784,753
New Jersey	6,220	10,433	1,492,202	2,517,764	3,103,927	3,625,890
Pennsylvania	438	2,220	94,801	976,011	276,600	284,031
Delaware	1,979	2,247	268,231	218,129	997,695	250,865
Maryland	26,008	39,944	6,342,443	7,465,718	5,221,715	6,460,759
Virginia	18,864	23,595	1,914,119	2,944,559	2,997,043	3,641,282
Total	59,853	90,685	12,685,331	19,405,151	16,360,517	19,047,580
South Atlantic:						
North Carolina	5,274	10,274	506,561	1,243,988	845,695	1,027,669
South Carolina	1,005	2,701	66,275	127,762	212,482	202,602
Georgia	899	1,622	78,770	174,431	119,993	123,563
Florida	368	1,541	43,554	146,895	78,108	236,060
Total	7,546	16,138	695,160	1,693,076	1,256,578	1,589,894

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[*] This year is placed at the head of the columns because it is the most recent one to which the statistics relate and the one to which most of the figures apply. The data for the New England, Middle Atlantic, and Pacific States are for that year; those for the South Atlantic States are for 1891, and those for the Gulf region and Great Lakes are for 1890.

Comparative summary of the fisheries of the United States in 1880 and 1892—Continued.

States.	Persons employed.		Capital invested.		Value of products.	
	1880.	1892.	1880.	1892.	1880.	1892.
Gulf:						
Florida	2,112	4,335	$362,563	$1,377,057	$564,819	$1,103,809
Alabama	635	618	38,200	135,290	119,275	154,871
Mississippi	186	1,721	8,800	434,710	22,540	245,699
Louisiana	1,597	4,068	93,621	719,876	392,610	681,284
Texas	601	1,277	42,400	319,122	128,300	313,832
Total	5,131	12,019	545,584	2,993,080	1,227,544	2,499,495
Pacific:						
California	3,094	5,426	1,139,675	2,526,962	1,860,714	3,044,781
Oregon	4,483	4,200	687,000	2,220,667	605,302	868,406
Washington	3,096	4,296	474,708	1,590,481	417,932	934,940
Alaska	6,130	2,849	447,000	2,535,703	2,661,640	2,410,848
Total	16,803	16,771	2,748,383	8,873,813	5,545,588	7,258,925
Great Lakes:						
New York	922	1,498	59,050	697,847	154,870	256,506
Pennsylvania	114	403	24,700	283,238	43,450	211,122
Ohio	1,046	2,738	473,800	1,874,900	518,420	618,683
Michigan	1,781	3,343	442,665	1,458,884	716,170	934,005
Indiana	52	94	29,360	21,549	32,740	21,693
Illinois	300	386	83,400	429,545	60,100	23,836
Wisconsin	800	1,225	222,840	481,374	253,100	399,272
Minnesota	35	51	10,160	170,743	5,200	6,238
Total	5,050	9,738	1,345,975	5,478,080	1,784,050	2,471,355
Grand total	131,426	182,376	37,958,040	58,242,708	38,683,348	45,312,818

One of the most instructive and important comparisons which may be made is that which exhibits the present and past condition of the shad fishery. The shad is the most important river fish of the Atlantic seaboard, and has been the subject of more extensive fish-cultural operations than have been undertaken in the interest of the preservation and increase of any other fish. The maintenance and increase of the supply of shad in recent years, in the face of an enormous annual catch, are, without question, attributable to artificial propagation carried on by the National and State fish commissions. The results achieved are among the most noticeable in the annals of fish-culture. From the following table it will be seen that the aggregate yield of shad in 1880 was 18,074,534 pounds, valued at $995,790. At that time the fishery in some of the principal rivers and coast waters was in an unsatisfactory condition and had been showing positive symptoms of a decline for a number of years. It was predicted in some regions that, under the conditions and methods then prevailing, the practical suspension of the fishery was imminent. It was about that time that the results of extensive fish-cultural operations were manifested. The supply of shad became greater and the abundance has steadily continued to increase, until in 1892 the yield amounted to 38,830,977 pounds, for which the fishermen received $1,879,688. While it is impossible, on the Atlantic coast, accurately to gauge the effects of propagation methods and to distinguish between the results of natural and artificial increase, the establishment of a shad fishery along the Pacific coast as the immediate sequence of relatively insignificant plants of fry in two or three rivers affords a reasonable basis for claiming the dependence on fish-culture of the Atlantic shad fishery.

The table shows the quantity and value of shad taken in each of the coast sections in 1880 and 1892:

Comparative table showing the results of the shad fishery of 1880 and 1892.

Sections.	1880.		1892.		Increase or decrease.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
New England	2, 117, 392	$88, 730	1, 085, 339	$43, 606	− 1, 032, 053	− $45, 124
Middle Atlantic	12, 024, 579	526, 982	27, 621, 440	1, 332, 854	+15, 696, 861	+ 805, 872
South Atlantic	3, 932, 565	380, 078	9, 385, 354	482, 403	+ 5, 452, 791	+ 102, 325
Pacific			738, 844	20, 825	+ 738, 844	+ 20, 825
Total	18, 074, 534	995, 790	38, 830, 977	1, 879, 688	+20, 756, 443	+ 883, 898

The changes that have taken place in the oyster production since **1880 have been among the most** noticeable features of the fisheries during that period. **The question of the preservation and increase of the** supply **has been widely discussed. The threatened exhaustion of** the natural beds in the most prolific sections **has drawn special attention** to the value of and necessity for artificial methods **in maintaining the crop.** The increased output shown by the table, while in some **States due to a development** of the natural resources, has in others been mainly **attributable to the application** of planting methods made possible by the enactment of **protective** and **stimulative** laws.

In the New England States the increased yield has been over **300** per cent, with **a reduction in the** average price to the consumer. In the principal oyster-producing **region, the** Middle Atlantic States, the increase is less than 5 per cent, with **an advance in the** average price per bushel. The South Atlantic section presents an **augmentation** in the yield of about 350 per cent, with a large diminution in the average **price, as is** also the case in the Gulf States, where the catch has increased over 500 **per cent.** The most remarkable change has occurred in the Pacific States, where in **1880** only 15,000 bushels of oysters, mostly native, were taken, while the annual **output** at the present time is between 300,000 and 400,000 bushels, in large part eastern oysters introduced as seed; the average price per bushel in 1880 was 66 cents, **while now** it is over **$2.50**, the demand for the more desirable oysters brought from **the Atlantic** coast being very great.

Considering the entire country, an increase has occurred since 1880 amounting to **6,067,000** bushels, having a value of $4,122,755, the average price increasing from 55 **cents to** 57 cents a bushel.

Comparison of the output of the oyster fishery in 1880 and 1892.

Sections.	1880.		1892.		Increase.	
	Bushels.	Value.	Bushels.	Value.	Bushels.	Value.
New England States	536, 650	$654, 775	2, 160, 863	$1, 751, 981	+1, 624, 213	+$1, 097, 206
Middle Atlantic States	20, 755, 540	10, 931, 527	21, 625, 931	12, 500, 759	+ 870, 391	+ 1, 569, 232
South Atlantic States	310, 000	120, 000	1, 192, 115	254, 141	+ 882, 115	+ 134, 141
Gulf States	578, 725	313, 200	2, 941, 014	796, 062	+2, 362, 289	+ 482, 862
Pacific States	15, 000	10, 000	343, 924	849, 314	+ 328, 924	+ 839, 314
Total	22, 195, 915	12, 029, 502	28, 263, 847	16, 152, 257	+6, 067, 932	+ 4, 122, 755

Among other important products the comparison of whose past and present abundance, as shown by the catch, may be of general interest, are bluefish, alewives, sea bass, squeteague, Spanish mackerel, salmon, cod, mackerel, and lobsters. Comparative figures for each of these are given by geographical sections in the following table:

Comparative statistics of the catch of certain products in 1880 and 1892.

Sections.	1880.		1892.		Increase or decrease.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
Alewives:						
New England States	9,728,261	$103,285	7,128,945	$102,029	− 2,599,316	− $1,256
Middle Atlantic States	19,901,072	267,527	35,503,455	286,605	+15,602,383	+ 19,078
South Atlantic States	16,055,000	155,734	16,543,783	166,106	+ 488,783	+ 10,372
Total	45,684,333	526,546	59,176,183	554,740	+13,491,850	+ 28,194
Bluefish:						
New England States	5,526,341	161,418	1,303,110	77,545	− 4,223,231	− 83,873
Middle Atlantic States	8,267,217	187,653	12,591,486	504,466	+ 4,324,269	+ 316,813
South Atlantic States	850,000	16,600	1,452,984	36,918	+ 602,984	+ 20,318
Gulf States	* 64,250	1,085	610,256	18,376	+ 546,006	+ 17,291
Total	14,707,708	366,756	15,957,836	637,305	+ 1,250,128	+ 270,549
Cod:						
New England States	110,282,350	3,286,525	84,334,990	2,745,613	−25,947,360	− 540,912
Middle Atlantic States	5,247,000	98,381	2,954,317	110,612	− 2,292,683	+ 12,231
Pacific States	3,608,000	90,200	5,354,504	140,466	+ 1,746,504	+ 50,266
Total	119,137,350	3,475,106	92,643,811	2,996,691	−26,493,539	− 478,415
Lobsters:						
New England States	19,946,733	620,821	22,983,951	1,023,751	+ 3,037,218	+ 402,930
Middle Atlantic States	291,950	10,948	317,198	26,926	+ 25,248	+ 15,978
Total	20,238,683	631,769	23,301,149	1,050,677	+ 3,062,466	+ 418,908
Mackerel:						
New England States	72,567,563	1,833,910	17,018,829	1,099,904	−55,548,734	− 734,006
Middle Atlantic States	750,000	† 30,000	22,907	2,747	− 727,093	− 27,253
Total	73,317,563	1,863,910	17,041,736	1,102,651	−56,275,827	− 761,259
Mullet:						
Middle Atlantic States	115,700	3,991	456,100	15,753	+ 340,400	+ 11,762
South Atlantic States	4,369,000	112,597	5,573,623	133,635	+ 1,204,623	+ 21,038
Gulf States	2,217,250	108,421	15,185,117	238,528	+12,967,867	+ 130,107
Total	6,701,950	225,009	21,214,840	387,916	+14,512,890	+ 162,907
Salmon.						
Atlantic States	111,324	21,952	138,549	20,166	+ 27,225	− 1,786
Pacific States	51,522,500	1,064,387	93,687,978	3,710,250	+42,165,478	+2,645,863
Total	51,633,824	1,086,339	93,826,527	3,730,416	+42,192,703	+2,644,077
Sea bass:						
New England States	629,450	21,511	1,928,440	95,386	+ 1,298,990	+ 73,875
Middle Atlantic States	1,486,200	76,485	5,593,429	231,820	+ 4,107,229	+ 155,335
South Atlantic States	527,000	15,180	879,684	28,396	+ 352,684	+ 13,216
Total	2,642,650	113,176	8,401,553	355,602	+ 5,758,903	+ 242,426
Spanish mackerel:						
New England States	3,260	295	4,285	1,026	+ 1,025	- 731
Middle Atlantic States	1,852,663	129,709	976,837	79,287	− 875,826	− 50,422
South Atlantic States	11,500	635	91,500	6,254	+ 80,000	- 5,619
Gulf States	20,000	1,000	700,459	42,692	- 680,450	+ 41,692
Total	1,887,423	131,639	1,773,081	129,259	− 114,342	− 2,380
Squeteague:						
New England States	532,060	18,622	1,415,220	48,243	- 883,160	- 29,621
Middle Atlantic States	12,694,500	363,045	15,597,713	469,751	- 2,903,213	+ 106,706
South Atlantic States	1,827,000	40,355	2,368,067	68,266	- 541,067	- 27,911
Gulf States	500,000	15,000	2,959,433	122,570	- 2,459,433	107,570
Total	15,483,560	437,022	22,340,433	708,830	- 6,856,873	- 271,808

* Partly estimated.

† Estimated.

The change in the relative positions of the different States, as determined by the value of the catch in 1880 and at this time, is a matter having considerable general interest. Massachusetts heads the list, followed, as in 1880, by Maryland and New York. Maine, which ranked fourth, gives place to Virginia, which formerly ranked sixth. New Jersey has the same position, viz, fifth. Alaska, which held the seventh place, is supplanted by California, and takes the rank California formerly occupied, viz, eighth. Delaware has dropped from the ninth to the twenty-first place. Connecticut advances one point, from 10 to 9. North Carolina remains in eleventh place. Michigan drops from the rank of 12 to that of 13, its place being taken by Washington, which moves upward four places. The remaining States which have increased their rank are Florida, from 14 to 10; Oregon, from 15 to 14; Washington, from 17 to 12; Louisiana, from 18 to 16; Pennsylvania, from 19 to 18; Wisconsin, from 20 to 19; Texas, from 23 to 20; Alabama, from 25 to 24; and Mississippi, from 28 to 22. The other States which have lost prestige are Ohio, which drops from 16 to 17; South Carolina, from 21 to 23; New Hampshire, from 22 to 26; Georgia, from 24 to 25; Illinois, from 26 to 27; and Indiana, from 27 to 28. Minnesota remains at the end of the list.

Table showing the relative rank, based on value of the products, of the coast and Great Lakes States in 1880 and 1892.

Rank.	1880.	1892.
1	Massachusetts	Massachusetts.
2	Maryland	Maryland.
3	New York	New York.
4	Maine	Virginia.
5	New Jersey	New Jersey.
6	Virginia	California.
7	Alaska	Alaska.
8	California	Maine.
9	Delaware	Connecticut.
10	Connecticut	Florida.
11	North Carolina	North Carolina.
12	Michigan	Washington.
13	Rhode Island	Michigan.
14	Florida	Oregon.
15	Oregon	Rhode Island.
16	Ohio	Louisiana.
17	Washington	Ohio.
18	Louisiana	Pennsylvania.
19	Pennsylvania	Wisconsin.
20	Wisconsin	Texas.
21	South Carolina	Delaware.
22	New Hampshire	Mississippi.
23	Texas	South Carolina.
24	Georgia	Alabama.
25	Alabama	Georgia.
26	Illinois	New Hampshire.
27	Indiana	Illinois.
28	Mississippi	Indiana.
29	Minnesota	Minnesota.

45.—THE FISHERIES OF JAPAN.

BY THE JAPANESE BUREAU OF AGRICULTURE.

INTRODUCTORY REMARKS.

The series of exhibits of the fisheries and fishing resources of Japan was brought together in order to give the visitor a glimpse into the fishing industries of the Japanese Empire. When the varieties of objects sought after are so numerous, and the methods employed for obtaining them are so diverse, as is the case in extensive fisheries, it becomes a serious question how appropriate selections may be made so as to form a sufficiently comprehensive and representative collection. In the present case, after much deliberation, the following plan has been adopted: Of the animals and plants found in our waters, those were at first selected whose respective annual yield exceeds 10,000 yen. As this, however, was found to exclude many objects of peculiar interest, exceptions have been freely made in favor of such special cases. The final selections as displayed in the present series consist of 138 species of animals and plants, as follows: Mammals, 3 species; reptiles, 2 species; fishes, 85 species; mollusca, 33 species; crustacea, 11 species; algae, 4 species.

By an unfortunate circumstance a species of Echinodermata, *Stichopus japonicus*, one of the important fishery products of Japan, was not included in the collection.

Of these species, alcoholic specimens, as far as possible, or photographs from actual specimens where they are too large, are displayed. In one or two cases of exceptional nature it has not been possible to follow this rule. The species are arranged in order of scientific classification, beginning with the *Cetacea* and going down the animal scale. Four species of seaweeds which are of great commercial interest are placed at the end.

Out of the 138 species mentioned above, those which are of great economic or social importance and are likely to interest the American and European public, have again been selected and made the subjects of a somewhat exhaustive display. Of each of these kinds, in addition to the alcoholic specimens or photographs, are given a map showing the distribution of the species, the various devices employed for catching it, such as hooks, traps, lines and nets, together with methods of culture where there are such, and finally the different articles manufactured from it. In some cases, where this full treatment is not possible or essential, only a part of the program has been carried out. The following subjects have been treated in this full manner, viz, the

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NOTE.—This paper has been abstracted and arranged from a descriptive catalogue of exhibits illustrating the fisheries and fishery resources of Japan, at the World's Columbian Exposition; the catalogue emanates from the bureau of agriculture of the department of agriculture and commerce of the Imperial Japanese Government. There is added an article on the fisheries of Japan by K. Ito, reprinted from the Transactions of the American Fisheries Society for 1887. The compilation has been made by Dr. H. M. Smith, assistant in charge of the division of methods and statistics of the fisheries.

whales and dolphins, the edible turtles, the "*tai*," the mackerel, the tunny, the bonito, the cod, the soles and flounders, the carp (with the goldfish), the salmon, the "*ayu*," the sardine, the herring, the oyster, the shrimps and lobsters; and the algae before referred to. By the adoption of this plan, it is hoped that a fairly representative display of the fishing industries of Japan has been secured.

The models of nets, boats, etc., have been made with the strictest fidelity to the originals, even in minute details, so that the actual things may again be constructed from them. Only, as it is impossible to reduce the size of the meshes in nets on the same scale with other parts of the models, the proportions of meshes in different parts of large nets are alone intended to be displayed.

When the size of the meshes is given in the description of the nets, it is to be understood as the distance between every two knots on the same straight line, when they are pulled as far apart as possible.

The prices given are all wholesale prices in the Japanese market. A yen (= 100 sen) is equal at the present rate of exchange to $0.65½ U. S. gold.

THE WHALE AND DOLPHIN FISHERIES.

The whales found in the seas adjacent to the Japanese coasts are the finback whale (*Balæna japonica*), the semi-kujira of the Japanese; the California gray whale (*Rhachianectes glaucus*), known among the Japanese as the ko-kujira; the humpback whale (*Megaptera boops?*), whose Japanese name is the zato-kujira; the rorqual (*Balænoptera arctica*), known in Japan as the iwashi-kujira or katsuwo-kujira; the sulphur-bottom whale (*Sibbaldius sulphureus?*), called nagasu-kujira in the language of the country; the sperm whale (*Physeter macrocephalus*), known as makko-kujira; and the sperm-whale porpoise (*Hyperoodon rostratus?*), whose Japanese equivalent is tsuchi-kujira. Of the porpoises and dolphins found in the waters of the country are the sunameri (*Neomeris phocænoides*), the goto-kujira or blackfish (*Globicephalus sieboldii*), the sakamata or grampus (*Grampus sakamata*), and the iruka or dolphin (*Delphinus longirostris*), the last named being the most common.

Dolphins and other small cetaceans are captured by means of nets. A dolphin net, exhibited by model in the Japanese section of the fisheries building, used at Tago in the province of Izu, consists of three separate nettings, called respectively the "closer," the "seine," and the "tuck-seine." The first is used for closing the mouth of the bay when the dolphins have entered it. It is made of straw ropes and the meshes are about 2 feet and 5 inches. The seine is used for encircling the dolphins and drawing them near the land. Its central portion is made of hemp, and the meshes are here about 8½ inches; while the two lateral portions are made of straw ropes with meshes of from about 2 feet to 2 feet and 5 inches. The tuck-seine is used for finally landing the dolphins. It is made entirely of straw and the meshes are about 8½ inches. Six boats are attached to it as floats.

The prepared products of this group of marine animals represented at the exposition consist of dolphin oil and crude and refined rorqual oil, manufactured by the Tokyo Fish Oil and Wax Company and exported to London, the price received being about 6 yen per 100 pounds. There were exhibited also crude and refined sperm whale oil, refined rorqual wax, and crude and refined spermaceti. The oil and wax of the sperm whale are produced only in small quantities. The price for the oil is 6 or 7 yen per 100 pounds; for the spermaceti, 15 or 18 yen per 100, and for the rorqual wax, 13 to 16 yen per 100.

SNAPPING-TURTLE CULTURE.

The snapping turtle (*Tryonix japonicus*), known in Japan as the suppon, is found in all parts of Japan in rivers and marshes, and is highly esteemed for the flavor of its flesh. Recently special attention has come to be given to its cultivation. The specimens exhibited were from the hatching-grounds of Mr. Kurajiro Hattori, of Tokyo. They comprised examples representing the stages of growth in the first, second, third, and fourth years after hatching. The breeding season is from the latter part of May to the first part of July, and the same individual is said to deposit eggs more than once in the course of a single season. The food consists of fish, shellfish, and worms. From about the middle of October to April of the next year the snapping turtle hibernates in the mud. Specimens two years old weigh from 10 to 13 ounces. Those weighing about 80 ounces are more than ten years old.

A map of the snapping-turtle farm of Mr. Kurajiro Hattori, of Tokyo, was exhibited. The pond has a muddy bottom, and its depth is about 1 foot near the banks and about 3 feet in the central part. The eggs are deposited in the sunny part of the bank. In the sandy area around the pond, which easily becomes dry, fences are erected to prevent the escape of the turtles. When the season for depositing the eggs is over, wooden boards of about 1 foot in height are erected on the lower margin of the bank and, between these, sheets made of reed or bamboo splints are placed to protect the broods from the attacks of their parents and other foes. Within the barrier are buried numerous pots to afford shelter to the newly hatched turtles.

The canned meat of the snapping turtle has a large demand, owing to its fine flavor and nutritious properties. The sample exhibited was made in the province of Chikugo. The price per dozen cans is 3.60 yen.

THE TAI FISHERY.

The tai,[*] as the Japanese call the scup, is the most highly esteemed of all the food-fishes of the country, and no feast can be complete without it. Of the four species of tai in Japanese waters, *Pagrus tumifrons* (called hanaore-dai), *P. cardinalis* (kasuko-dai), *P. major*, and *P. ruber*, the second named is the most abundant. The tai of the market is generally from 1 to 2 feet long. The price of a fresh tai a foot in length is often more than a yen. The tai is a bottom fish preferring sandy or muddy places. It feeds on other fishes, shellfish, and annelids. In the early part of summer it migrates from the deeper to the shallower seas, where it spawns, and in the autumn it again seeks its deep-water haunts. In the southwestern provinces the chief supply of the market-fish comes from the Inland Sea, the middle portion of which is a favorite spawning-ground. The tai enter the sea through its eastern and western channels, and returning seek the ocean by the same route. In the northeastern part of the country the spawning season is July and August. The tai is found in all parts of the country.

In fishing for the tai long lines or set lines, hand lines, and several forms of nets are used. The box of long line exhibited represents such an apparatus as is used at Misaki in the province of Sagami. It is a long line bearing a certain number of snoods about 20 feet long. A section of about 1,900 feet of the line bearing 85 snoods is put into a shallow round wooden box. A single boat manned by six or seven men often works a line of as many as twelve of these sections. A stone and a barrel buoy are attached to each section of the line as it is let down, except the first, to which is attached, instead of the stone, a wooden grapnel to fasten it to the bottom. When the whole line has been let down, a stone and a buoy are tied to its end; the boat is then rowed back, and the line is taken up from its beginning. For bait spoon-worms (*Echiurus*), sardines, and squids are used.

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[*] Changed into *dai* for the sake of euphony when compounded with a prefix.

The whole length of the tai hand line is 160 feet, of which the leader, 100 feet in length, is made of silk-worm gut, the remaining part being of silk. At three points a lead of one-tenth to one-fifth ounce is tied to hold line against the currents. When the line is used, the bamboo rod on which the line is reeled when not in use is employed as a fishing rod.

For bait, shrimps covered with *Mysis* are used, the *Mysis* serving as a toll bait.

Tai hooks of different kinds are used in various parts of Japan. Those made of brass are mostly used with the long line, while those of iron are generally used with the hand line. They are of various shapes; some angular, others are curved; some possess barbs, others have none, while in still others the end is bent laterally at an angle. Some are made simply by bending a wire, while others are carefully tempered.

The principal net used in the tai fishery is the scare-cord seine.

This net is called "katsura-ami" by the native fishermen, from the idea that its scare-cord resembles in appearance the stem of the ivy (katsura=ivy, ami=net). The meshes are largest near the ends of the two wings, where they measure about 5 feet, and gradually diminishing in size become at last about half an inch in the central portion. The portion with smaller meshes is made of hemp, while those portions which have larger meshes are made of straw. The net is divided along its middle line into portions which are joined together when used.

The scare-cord is made of hemp and is about 3,750 feet long. To it are attached, at intervals of 2 feet, thin rectangular pieces of wood. Also to keep the cord in a horizontal position at a proper depth, stones and barrel buoys are tied to it.

To work the net, each end of the scare-cord is kept by a boat. The two boats, keeping at a convenient distance from each other, row in conjunction, and, gathering together the scattered fish, scare them on the net, which is kept spread by two other boats which also gather it in after the fish have entered.

In addition to being extensively consumed in a fresh condition, the tai is preserved in various ways, viz, with salt, by being opened and dried; or by being boiled and crushed; or again by being made into wafers. Salting is, however, the chief means of preservation. Salt tai is largely made along the southern Pacific coasts of Japan, more than 10,000 casks being produced every year. The price varies according to the size and quality of the fish salted, but about 5 yen per 100 pounds may be taken as the current wholesale price.

Tai wafers are excellent for making soup. Neither taste nor color is affected by lapse of time. Mashed tai (Japanese, tai-dembu) is excellent for making broth. It has a delicate flavor which is very delicious. The price is about 50 sen a pound.

THE MACKEREL FISHERY.

The species of mackerel sought by the Japanese is *Scomber colias*, which is known by the name săba.

Fishermen distinguish several kinds of "saba," such as "maru saba," "hira saba," and "goma saba;" but they are probably to be regarded merely as varieties of the species named above. This species is always found in or near the Kuro-Shiwo or

Black Stream; but nothing is as yet known about its migration. In its pursuit of prey it comes into bays and shallow waters near the coast, and can then be caught with ground-seines. At night it is easily attracted by light, and the fishermen take large shoals by burning torches in their boats.

The food of the mackerel consists principally of sardines, small crustaceans, squids, and pteropods; but it is not very fastidious in its taste and takes even salt fish. Spawning takes place in April and May. Large specimens often measure about 2 feet in length and weigh about 6 pounds.

Mackerel fishing is carried on in all parts of Japan. Both nets and lines are used for the purpose, but the latter are by far the more effective means.

A mackerel long line used at Misaka in the province of Sagami, which may be taken as a type of this form of line, is about 350 feet long, bearing 85 snoods of about 2 feet. Fourteen baskets of this line are usually worked by a boat of 6 or 7 men. When being used, the line is kept floating at some intermediate depth by means of five barrel buoys attached to the principal line by means of ropes 300 to 350 feet long. As ballast a small stone is tied to the lower end of each hanging rope. Beside these, nine smaller stones are attached at intervals to the whole line.

A mackerel hand line, locally called bishi, used in the same place, consists of a piece of brass wire bent in the middle so as to form a loop, the two ends of which diverge from each other. The wire is then attached by the loop to a line consisting of three strands coiled together, and measuring about 250 feet in length. Each end of the wire bears a snood of silk-worm gut, and to the loop are attached a conical piece of lead and a bag containing bait. This line is worked by night and at a depth of 10 to 50 fathoms with good tidal currents; large shoals being made to gather by torch or lamp light.

For bait, sardines and mackerel are chiefly used. When these can not be obtained fresh, salt sardines or salt mackerel are used; the small bag attached to the loop contains minced flesh of these fish, which acts as a toll bait.

The mackerel is caught in considerable numbers in the spring and autumn, but also more or less throughout the year.

A mackerel torchlight net is used near the coast of the southern parts of Japan. The whole is a rectangular net 60 feet by 210 feet, the central portion being made to hang down slack and form a sort of bag. Its meshes vary in different parts from half an inch to about 6 inches. Four ropes made of straw are tied to the short sides of the net and five to the long sides. At the junction of the net and the rope a stone (of 8 to 10 pounds) is attached. The net is first of all kept spread flat by four boats holding the ropes tied to the sides. Two boats with dragons then row on to the middle of the net. A large number of mackerel, attracted by the lights, follow them. Then the men in the four boats begin to work in the ropes, and the boats with dragons extinguish them and row out of the net. This mode of attracting large numbers of the mackerel with torchlights has been in use in Japan for 400 years.

There are three ways of preserving the mackerel, viz, drying, canning, and salting. Of these, salting is carried on on an extensive scale in every part of Japan. In recent years various improvements, such as the use of specially selected salt, have been introduced, and fine salt mackerel is now not a rare article in the market. If there should be any demand for exportation in future, this mode of curing would doubtless attain a still higher degree of perfection.

Salted mackerel are put on the market in casks of several sizes; a small cask, containing 8 or 9 fish from 1 to 1½ feet in length and weighing about 10 pounds, commands the price of 1 yen; a larger cask, holding 14 mackerel weighing twice as much as the first cask, sells for 2 yen. The value of the salt mackerel packed in 1890 was 234,561 yen; and in 1891 it was 183,686 yen.

THE TUNNY FISHERY.

The tunnies—*Thynnus sibi* and *T. albacora*, the shibi and kiwada-shibi, respectively, of the Japanese—move in large schools in the Kuro-Shiwo but never enter bays or inland seas. They are carnivorous and feed on small fishes and squids, being often seen dancing around shoals of small fish and eating them. They are very quick in their movements and are good swimmers. Specimens 5 feet long and weighing over 124 pounds are quite common. The tunnies are caught throughout the year, but summer is the best fishing season. They are caught with trawl lines and in pound nets.

The tunny long line is a cord of about 1,250 feet with 10 snoods about 5 feet long, and is worked at a depth of more than 400 feet. Both the cord and the snoods are made of hemp, and put into shallow baskets. Two boats, with 8 or 9 men each, usually work 12 basketfuls of the cord. To use it, 5 stones weighing about 27 ounces apiece are tied to the cord; also at each end of it is attached, by means of a cord about 300 feet long, a rod of *Paulownia imperialis*. To these again is tied at right angles a long stem of bamboo, at the top of which some easily observable signals are placed. The principal cord does not reach the bottom of the sea, but is kept suspended at some intermediate depth. For bait, squids and horse-mackerel are used.

The hooks are made of brass castings.

The pound net used in tunny fishing is a fixed net made of straw on a large scale and with great art. It is used at the extremities of wooded promontories in the vicinity of Nagasaki. It consists of two principal parts, the leader and the bowl. The leader, which is set near the coast, has 1-foot meshes. In the bowl the meshes at first are also about 1 foot, but become smaller as they approach that portion which is made of ropes of straw. The net is fixed by stones, some of which are attached to the lower margin of the barrier, and others are put into nets and suspended by ropes of straw from the floats consisting of bundles of bamboo tied to the upper margin of the net. The leader is about 1,150 feet long and 20 feet high, while the bowl is about 350 feet long and 280 feet wide. Two watchmen are always placed on a watchtower to keep a lookout. When the fish enter the bowl along the barrier, a net which is placed at the entrance of the bowl is in the first place drawn up, and the fish are caught in the inner pound by gradually raising up the net of the pound. When, however, they do not enter the bowl directly, the entrance into the pound is closed with another net and the fish are driven into the bowl.

A double pound net set for tunnies is used in the seas near Sendai in the northern part of Japan. It consists of a leader and a pouch. The former is about 1,750 feet long and its meshes are about 5 feet; the latter is about 1,740 feet in circumference and its two blind ends form the inner pound. There are five intercepting nets, viz, one at the entrance of the pouch, another on each side of this, and others at the entrance of each inner pound. These nets are usually allowed to hang down; but when the fish enter the pouch they are successively raised and lowered, so that the fish are gradually driven into the inner pound. The whole net is provided with stones and with floats of unhewn timber. The meshes of the pouch vary from about 1 foot 4 inches to about half an inch in length.

This net proves itself to have been constructed with a full knowledge of the habits of the fish for which it is intended. Owing to the presence of a rectangular bend in the barrier and the curvature of the pouch, the fish which have once entered the net can not possibly get out of it again. Moreover, if a second shoal of fish comes after the first has entered the pouch the latter is driven beyond the second intercepting net, and the net at the entrance of the pouch is opened; then the second shoal merely swims to and fro between the barrier and the entrance of the pouch for any length of time, and there is no fear of their escape.

In the watchtower 2 men always keep a lookout, while below is a boat with 6 men. When the fish enter the net, word is given from the tower to the boat and the intercepting nets are put into action. Moreover, signals are made to the fishermen's huts on the shore, according to the number of fish.

The tunny drift net is used in the vicinity of the Bay of Tokyo. A single netting is about 275 feet long and 20 feet wide. Twelve such pieces (or "mogai," as the fishermen call them, are joined into a single net. The meshes are about 7 inches, and the knots are made so as to prevent sliding in either direction. A big rope is tied to the upper margin. In order to make the net float on the surface, the rope is made from the fibers of the palm (*Trachycarpus excelsa*), and floats are attached to it at a distance of about every 1 foot 4 inches. The rope of the lower margin is made of hemp, and no stones are attached to it.

This net is worked in the spring and in the open sea at a depth of 500 to 1,000 feet. Many boats form a line and intercept the route of the fish, and the net is shot down the tidal current. While being drifted, one end of the net is kept tied to the boat, while the other end is attached to a float, with a floating signal and a lighted lamp.

Tunnies are mostly eaten raw in Japan. Until recently the only methods of preservation were by salting, and by smoking and drying; but now they are also canned and preserved in oil according to European methods. The only method which offers any peculiarities is smoking. As preliminary to that process, the flesh is first boiled in water, and after being smoked is dried. It can be kept for any length of time without any alteration in its taste. It is daily used in Japanese households as a condiment, and is especially excellent as a stock for soup. One hundred pounds cost 12 to 15 yen.

THE BONITO FISHERY.

The fishes embraced by the name bonito include a number of scombroid species, chief among which in Japan are *Thynnus pelamys*, called Katsuwo,* and *Auxis tapeinosoma*, called Soda-gatsuwa.

These two fishes, especially the first, are of prime importance in the fisheries of Japan; and the amount of their catch directly affects the monetary condition of the fishing villages. They are both migratory fishes. Coming in the spring in large shoals along with the *Kuro-Shiwo* from the southern seas, they pass the summer about submarine rocks near the coast, and go back to the south in the autumn; but of the details of their routes, their habits, and the time and place of their spawning, nothing accurate is known. Large specimens often measure about 1 foot and 5 or 6 inches in length and weigh about 12[illegible] pounds. The bonito as well as the *sōda* feeds on smaller fishes; but they have a very fastidious appetite, so that dead fish can not be used for bait. The *sōda* comes nearer the coast than does the bonito.

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*Changed into gatsuwo when compounded with a prefix.

Both nets and lines are used in bonito fishing; but angling with bamboo rods is the chief means of fishing, and it has attained a high degree of perfection. The bonito being found chiefly near hidden rocks and in rapid currents, nets can not be used to advantage.

The hooks for fishing bonito are of two kinds, viz, those used with true baits and those with artificial baits attached to them. In the latter the artificial baits are made to resemble both in form and color either sardines or squids.

A fishing scene off the Shiwono Misaki, in the province of Kii, illustrated in the Japanese section, represents the method of angling for bonito. The man in the middle of the boat, lifting up his right hand and holding a dipper in his left, is casting sardines into the water to attract the fish; 2 men near the stern with fishing-rods in their left hands and with long bamboo rods in their right hands, are throwing water on the bait by means of spatulas attached to the end of the bamboo rods, so that the fish may not see the line and the hook above the bait; a man near the prow has succeeded in catching a fish and has just freed it from the hook by holding it under his arm; a man at the stern has caught a large fish, and a boy is about to raise it up with a hook. The man at the stern with his face turned toward the right side of the boat in the [illegible]. He is using a hook with artificial bait.

A bonito circle net is used at the entrance of the Bay of Tokyo from the latter part of autumn to the early part of winter. The bunt is made of hemp, but the wings are made of straw. The net is made up of two halves, each measuring about [illegible] feet in length. The meshes are from about 2[illegible] inches to 5 feet. To work this net 4 boats with [illegible] men are required. Of these the 2 smaller boats serve as leaders, searching out the school of fish and giving orders. When the signal is given, the other boats, which have hitherto carried the two halves of the net separately, join them together and encircle the school. The wings are gradually hauled in and the fish are driven into the bunt.

The bonito is to a certain extent eaten raw; but nine-tenths of the fish caught are smoked and dried for preservation. Some are also preserved in salt, but very rarely. [illegible] like the [illegible], and oil and scrap are also prepared from it.

In smoking bonito the fish is cut lengthwise along the spine and the lateral lines and the [illegible] and the head, tail, fins and bones are removed. The pieces are then [illegible]. The bonito thus treated can be kept for any length of time without any change in its taste. It is shaved into small pieces and used as a [illegible] Japanese culinary art. [illegible]

THE COD FISHERY.

Two species of cod are objects of fisheries in Japan; these are *Gadus brandti* (Japanese tără*) and *Gadus chalcogrammus* (Japanese suketŏ-dără). The cod are gregarious bottom fish living at a depth of more than 500 feet and limited to those seas which are within the reach of cold currents. Cod fishing is mostly carried on in January and February, when the fish come near the shore for spawning. In some places they come up to a depth of about 100 feet, but in others are never found at a depth of less than 650 feet. They feed on herrings, lampreys, squids, and lobsters. The first-named species is the more abundant and important, the other being found chiefly near Niigata.

Cod fishing is carried on with long lines, hand lines, gill nets, and pound nets. The long line is more commonly used than the hand line, and the gill net than the pound net, the latter being restricted to a single locality.

The two baskets of long lines exhibited are such as are used near Niigata in fishing for *Gadus chalcogrammus*. It is a line 225 feet long, bearing 55 snoods of about 2 feet each. Such a line is put into a shallow basket made of bamboo, and is called a "maki." A boat of 6 men uses 80 such "*maki*" tied end to end into a single line; at each end and in the middle are tied a stone and a barrel buoy, the latter by means of a cord; also at the end of each "*maki*" are attached alternately a small stone and a float, so that the whole line may not lie flat on the bottom, but be kept floating at intervals. For bait, sardines and squids, cut into pieces of convenient size, are used.

The cod gill net is a hempen net used along the shores of the Sea of Japan for catching *Gadus chalcogrammus*. For this purpose it is sunk to the bottom of the sea. A single piece is about 1,212 feet long and about 5 feet high, and the meshes are about 3 inches. For floats, pieces of varnish-tree or of *Paulownia imperialis* are used, and for grapnels stone and wood. A single boat uses several pieces joined together. For *Gadus brandti* nets with larger meshes and made of bigger cords are used.

The cod is but little eaten in a fresh condition. The fish is cured in different ways and exported to various countries. Pressed cod is made in Hokkaido after the American method. One hundred pounds cost about 12 yen. Split cod are slightly salted and then dried in the sun. A hundred pounds cost 5 or 6 yen. The yearly produce represents from 40,000 to 50,000 yen, or over 800,000 pounds.

Cod-liver oil is manufactured in Hokkaido and sold in bottles containing a pound each. This is used exclusively for medicine. A dozen of such bottles cost about 2 yen and 4 sen. The yearly produce is increasing.

THE SOLE AND FLOUNDER FISHERIES.

Many species of flattishes are found in the waters of Japan. Among the most important are *Pseudorhombus cinnamoneus* (called kanzō-hiramé), *P. olivaceus* (hiramé), *Parophrys cornuta* (meita-garei), *Pleuronectes scutifer* (ishi-garei), *P. variegata* (hoshi-garei), and *Plagusia japonica* (ushinoshita-garei). They are all bottom fishes and spawn mostly in winter.

In the capture of these fishes both nets and lines are used; but the former, of which gill nets, trawls, and dredges are employed, are the chief means by which most of the market fish are obtained. The lines are either the long or the hand line.

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*Changed into dara when compounded with a prefix.

The plaice hand line is a double coil line about 50 fathoms long bearing 30 pieces of lead each weighing about 2¼ ounces. These pieces of lead serve to hold the line against the current. The distances between them grow less and less as we approach the hook. To the hook is attached a flat circular piece of lead, and beside this there is a long line for tying the bait, for which sardines, either fresh or salted, are used.

A form of pole-trawl for soles and flounders, such as is used in the seas near the province of Owari, was exhibited. It consists of a pouch with two wings and a netting stretched between their upper margins. The pouch is about 21 feet long, and its meshes are from a little less than 1½ to about 2 inches. The wings are about 30 feet long and their meshes are about 2 inches. To prevent any damage to the pouch, a hempen netting with meshes of about 3½ inches is spread below it; this is worked with full sail at a depth of 100 to 200 feet. To keep the pouch and the wings open, a long pole is projected from each end of the boat, and to these the drag-ropes are tied.

The plaice gill net is made of hemp. A single netting is about 165 feet long and 6 feet high, and the meshes are about 6 inches. To the upper margin is attached a strong rope of straw with wooden buoys, and to the lower a similar rope with stones. When being used, from ten to twenty of such nettings are joined into a single net, to one end of which are then tied a wooden grapnel and a float. The net is used on sandy bottoms at the depth of 50 to 60 feet.

The flatfish are mostly eaten raw, only a small proportion being dried for preservation. They are also pressed for oil. Dried flounders are chiefly prepared on the coasts of the inland sea. They are mostly sold to the mountain villagers. Flounder oil is a by-product in the preparation of the preceding; it is used for lighting purposes in some retired localities. A scrap, made by pressing flounders, is used in agriculture.

CARP AND GOLDFISH.

The carp (*Cyprinus carpio*) is a food-fish of considerable importance in parts of Japan. A form of weir intended for the capture of carp and crucian carp is used in Lake Biwa in the province of Omi. It is made of bamboo splints and for posts bamboo poles are used. The weir consists of three inclosures which, however, have no intimate relation with one another, but are complete each by itself. Of these three, that nearest the bank is small and low, being about 10 feet high, and the intervals between the splints being a little over one-fourth of an inch wide. The next one is a little larger, being about 12 feet high with the intervals between the splints about ¾ of an inch. The last inclosure is largest, and is about 15 feet high with the intervals between the splints about 1¾ inches. It is intended mainly for carps and crucian carps.

Of the goldfish (*Carassius auratus*) we distinguish three varieties, viz, ***ryukin***, *wakin*, and *maruko*. Various other names are given, according to the form of the caudal fin. The most costly form is the so-called "lion-head" variety of Maruko, which has numerous warts on its head. A pair of this variety, male and female, often costs more than 100 yen; and even the most common specimen can not be obtained for less than 5 yen. The goldfish spawns from the latter part of April. The cultivators usually make their fish spawn three times with intervals of about one week.

THE SALMON FISHERY.

The spring salmon (*Oncorhynchus perryi*) and fall salmon (*O. haberi*), called sàké by the Japanese, are found in the northern parts of Japan, especially in Hokkaido. They ascend the rivers of those parts for spawning, and at that season undergo a great change in shape as well as in color. They usually attain the length of about 3 feet, and weigh 12 to 17 pounds, but large specimens sometimes measure about 4 feet in length and weigh about 20 pounds.

In fishing for salmon drift nets, tow seines, circle nets, and pound nets are used; the first and the last most commonly.

The salmon pound net is employed along the coast of the province of Tokachi in Hokkaido. It consists of a large bowl made of hemp and a leader made of straw. The latter is 750 to 1,500 feet long and its meshes are 2½ to 7 inches. Intercepted by the leader, the fish follow it and enter the bowl. At this time a netting which has hitherto been kept lowered is raised, and the mouth of the bowl is closed. The fish are landed by gradually tucking in the bowl.

The salmon drift gill net exhibited is such a form as is used in the provinces of Uzen and Ugo. It is made of hemp, and a single netting is about 175 feet long and 8¼ feet high. Floats are tied to the upper margin, but the lower margin has no weight attached to it. It is worked by night at the mouths of rivers from about the middle of October till the first part of December. Eight or ten nettings are usually joined into a single net, and are shot down the stream.

In addition to being consumed in a fresh condition, salmon are placed on the market in a salted, smoked, and canned state. Salt salmon forms the greater bulk of the salmon cured for preservation. The price has risen in recent years in consequence of exportation, and a single fish now costs 30 to 40 sen. Salmon are not smoked in large quantities, as the demand is not very great. The price is accordingly high, a single box containing 10 fish costing about 2.50 yen. Canned salmon is largely made in Hokkaido; more than 200,000 cans, amounting in value to about 24,000 yen, are sold every year.

THE AYU FISHERY.

The ayu (*Plecoglossus altivelis*) is very highly esteemed among the fresh-water food-fishes. It lives in sandy rivers, and is found in almost all parts of Japan. It feeds chiefly on diatoms and other lower algæ. Large specimens measure sometimes more than a foot in length. It spawns in autumn, in shallow rapids.

In fishing for the ayu, lines provided with fly hooks and ordinary hooks are used; scare-cord and casting nets are also employed. Beside these there is a peculiar mode of fishing with tame cormorants, called *ukai*.

The ayu scare-cord net consists of a receiving net and a scare-cord. The former is made of hemp, and its meshes are about an inch. The scare-cord is also made of hemp and is from 200 to 250 feet in length. It bears at intervals short branch lines, also of hemp, to the extremities of which are attached feathers of the cormorant. A single man keeps the receiving net open against the current, while four men scare the fish down the stream with the cord and drive them into the net.

A graphic model of the method of ayu fishing with tame cormorants, or *ukai*, shown in the exposition, represents a single *ukai* boat of the River Nigara, in the province of Mino. A dragon is placed at the prow to help the maneuvers of the cormorants. The men are four in number, of whom two manage the boat and the other two the cormorants. The skill with which the men handle the birds is truly wonderful. The man near the prow usually manages 12 birds, and when one of them swallows four or five fish he draws it to him by the cord with which it is tied, and by pressing its throat squeezes the fish out into a tray beside him. In doing this, he is always sure to pick out the right cord, and not the least entanglement occurs. The large basket with the wooden cover is used for keeping the cormorants in. This mode of fishing is said to have begun more than a thousand years ago.

The ayu is highly esteemed in the fresh state; but it is also boiled and dried, or preserved in salt and *saké* dregs, so that it may be kept for a long time or transported to distant countries. The ayu thus treated is highly esteemed and is sold at a high price. When preserved in the dregs of *saké*, or Japanese wine, the fish is stuffed with its own roe. The value of a single fish is about 50 sen.

THE SARDINE FISHERY.

The sardine or iwashi (*Clupea melanosticta*) is the most important of the useful fish of Japan, and the economic condition of the whole fishing industry is intimately connected with the amount of its catch. This is due to the fact that the sardine always comes in enormous shoals and is caught almost everywhere along the coast. Large areas of the surface of the sea are sometimes changed in color by the presence of a single shoal. The sardine is a migratory fish, going from south to north in spring and returning again to the south in autumn. The shoal usually swims at the surface, against the current, but is said also to sink at times to the bottom. The sardine feeds on small crustaceans, such as *Mysis*, and is attracted by torchlight. Spawning takes place in the spring.

Both nets and lines are used for sardine fishing. The latter are, however, limited to certain small districts, while the former are extensively used and have been greatly improved, there being no less than twenty different types of them, the most important of which are the ground seine, circle net, eight-armed net, tack seine, dip net, and drift net.

The sardine ground seine is used at Kujūkuri in the province of Kazusa. It consists of a pocket and two wings. The pocket is made of hemp, with meshes of from ¾ to ⅞ of an inch, and is about 150 feet long. The wings are about 1,150 feet long, and are made partly of hemp and partly of straw. The hempen portion has meshes of from ¾ of an inch to about 2½ inches, and the straw portion has meshes of about 1 foot. The wings and the pocket can be separated from each other. The drag ropes are made of three strands coiled together, and are a little over an inch thick and 105 or 110 feet long. From 60 to 80 such ropes are usually provided ready for use. If a shoal is detected, two boats row out with the separate portions of the net. A little before reaching the shoal, the pocket and the wings are joined together; the former is then cast first and the shoal is gradually encircled with the wings. When these come to an end, the drag ropes are cast and the net is hauled on shore.

The circle net is called hassaku-ami by the native fishermen. It is used off the coast of the province of Hidachi. It consists of a central portion and two wings. It is usually separated at the middle into two equal portions, and these are joined together when the net is being used. The central portion is made of hemp and is 400 feet long, the meshes being from about five-eighths of an inch to a little over 1 inch (about 1⅛ inches). The wings are made of straw and are about 700 feet long, the meshes being 1 foot. To work the net 4 boats with over 50 men are required. Two of the boats carry the net separately and act according to the orders of the other 2 boats, which go in search of the fish.

The eight-armed net is a flat net used on the Pacific shores of Japan. It is almost square in shape, and the meshes are from a little over half an inch to about 1⅕ inches. To one side of the square are attached floats and to the remaining three sides ropes are tied. To the bottom of the ropes of the lower margin large weights of lead are attached. When in use the ropes of the three sides are held by 3 boats and the net is lowered obliquely against the current. When the shoal of fish comes over it the ropes are raised and the net is gradually drawn up, the fish being finally transferred to the boats.

The tuck seine is employed on the Pacific shores of the main island and closely resembles the purse net of the American fishermen. It is about 600 feet long and 65 or 70 feet wide at the two ends. The meshes are from about ¾ of an inch to a little over 1 inch. When not in use the net is carried in equal portions by 2 boats.

The dip net is operated on the Pacific shores of the main island. It is nearly square, each side about 35 feet, and the meshes are from about half an inch to about 1⅜ inches. To prepare it for use one side is stretched and made fast lengthwise to a bamboo rod, and to the opposite side 3 ropes, with stones attached, are tied. To each end of the bamboo rod another rod of bamboo is made fast.

To work this net the right side of the boat is, in the first place, turned against the current and the net is made to dip down from the left side; the bamboo rod to which one side of the net has been made fast is kept horizontal at a short distance from the boat by means of the two other rods. Some shrimp (*Mysis*) are then strewn on the right side, and the fish are called together; some more are then strewn on the left side, and when the fish come over it the net is drawn up by means of the ropes. This net is used in getting the sardines used as bait for the bonito. It is therefore made on a small scale, and the fish caught are kept alive in the well of the boat.

The sample of sardine drift net exhibited represents the form in use in the Bay of Tokyo. A single netting is about 150 feet by about 35 feet, and is made of hemp. The meshes are from about 1⅕ inches to about 1⅜ inches. The cord of the upper margin is made of hemp, and a lead is attached at every 3 feet. The rope of the lower margin is made of the fibers of the palm (*Trachycarpus excelsa*), and at about every 4 inches a wooden float is attached. A single boat with 6 or 7 men uses 7 or 8 nettings joined together. Fifty or 60 such boats usually form themselves into a line and the net is shot across the course of the sardines. This net is worked at night.

The sardines are caught in enormous numbers, and the greater part are dried and made into fertilizer, either entire or after the oil has been extracted. Recently, however, sardines have been canned and smoked, and their value has consequently increased. Smoked sardines promise to become a valuable article of export. "Gill-struck" and "back-split" sardines are used for food in the mountainous districts of Japan. Refined sardine oil, a by-product in the manufacture of scrap, is a very valuable exported product; over 2,500,000 pounds are annually made an [illegible]nt to various parts of Europe and America.

THE HERRING FISHERY.

The herring or nishin (*Clupea harengus*) is economically a very important fish in Japan. From the latter part of spring to the beginning of summer, it comes in large shoals to the adjacent seas and deposits its eggs on stony bottoms overgrown by seaweeds. The most famous-fishing ground is the west coast of Hokkaido; but the fish is found more or less in all parts of our northern seas where there is a cold undercurrent in winter and spring.

Herring fishing is carried on only by means of nets. Of these, gill nets, flat nets, and pound nets are used.

The model of the pound net shown in the Japanese section represents a fixed net used in Hokkaido. The pound is rectangular in shape and its nettings are made of hemp. The longer side of the pound is about 170 feet long, and its meshes are about 3 inches in the front part, while in the greater portion of the back part they are about 1 inch. On both sides of the entrance of the pound are the wings made of straw rope with the meshes about 3 inches. The leader is perfectly straight, and is 500 to 1,500 feet long. It is also made of straw rope, and the meshes are about 5 inches.

The most striking feature of this net is the so-called bag-net boat (Jap. wăku-ămi-buné), that is, a boat with a flat bag shaped net suspended under it from the sides. It is placed at the closed end of the pound, and the bag net is joined to the pound by one of its sides. When a shoal of herring enters the pound, a boat at its entrance takes up the rope and draws up the net, and on its approaching the end of the pound, the fishermen in the bag-net boat allow the joining line of the bag net and the pound to sink somewhat below the surface of the sea, and the fish are passed on into the former. The joining line is then again raised, and when, after repeating this process a number of times, the bag net is filled, the boat leaves its post to be taken by another, and rows for the coast, where the fish are bailed.

A single herring gill net is about 20 feet by 7 feet, and the meshes are about 2 inches. A single boat of 2 or 3 men uses usually twenty-five to fifty nettings, and five nettings are joined into a single group. Between each netting a weight of 4 to 5 pounds is attached, and to each group a float and a weight are tied. A number of these groups are set in a single line parallel to the coast.

The forms in which herring are put on the market are various. For food purposes the fish are prepared by salting, smoking, and drying. The yearly production of salt herring is increasing. The price per barrel is 1 yen. Smoked herring is put up in Hokkaido and the northern provinces of the main island. The sample exhibited has been prepared by the German method. The current price is 20 sen for ten fish. Dried herring slivers, dried split herring, and dried back-split herring are used for food in retired districts among the mountains. They are all sun-dried. The dried sliver is most largely used. Herring scrap is the substance that remains after boiled herrings have been pressed for oil. It is the best fish fertilizer, and is consequently highly valued and produced in large quantities. In 1889, 4,002,145 yen's worth was produced. Price per 100 pounds, 2.50 yen.

The dried refuse from slivered herring is used abundantly as fertilizer. Crude and refined oil and wax are produced in large quantities, 17,500,000 pounds of the oil being produced yearly. Both the oil and the wax have a large demand in Japan, and are also exported in large quantities.

OYSTERS AND OTHER MOLLUSKS.

Among the mollusks of economic importance in Japan, the following, represented in the exhibit by specimens, photographs, etc., may be mentioned:

Octopus octopodia (Jap. Ma-Dako).[*]
Octopus megalocyathus (Jap. Yanigi-Dako).
Octopus ocellatus (Jap. Ii-Dako).
Ommastrephes oualaniensis (Jap. Surumé-Ika).
Loligo vulgaris (Jap. Yari-Ika).
Sepioteuthis lessoniana (Jap. Awori-Ika).
Sepia sp. (Jap. Hari-Ika).
Rapana bezoar (Jap. Aka-Nishi).
Triton sauliæ (Jap. Hora-Gai).[†]
Turbo cornutus (Jap. Sazai).
Haliotis gigantea (Jap. Awabi).
Haliotis verginea (Jap. Tokobushi).
Lutraria nuttalli (Jap. Mirukui).
Siliquaria constricta (Jap. Agemaki).
Mactra sulcataria (Jap. Baka-Gai).
Trigonella sachalinensis (Jap. Uba-Gai or Hokki-Gai).
Cytherea meretrix (Jap. Hamaguri).
Dosinia troscheli (Jap. Manju-Gai).
Tapes philipinarum (Jap. Asari).
Corbicula atrata (Jap. Shijimi).
Cardium japonicum (Jap. Tori-Gai).
Tridacna gigas (Jap. Shako-Gai).
Arca inflata (Jap. Aka-Gai).
Arca subcrenata (Jap. Sarubō).
Arca granosa (Jap. Hai-Gai).
Mytilus crassitesta (Jap. I-Gai).
Pinna japonica (Jap. Tairagi).
Pinna sp. (Jap. Kuro-Mabé).
Avicula martensii (Jap. Akoya-Gai).
Pecten yessoensis (Jap. Hotate-Gai).
Pecten laqueatus (Jap. Itaya-Gai).
Ostrea cucullata (Jap. Kaki).[‡]
Ostrea denselamellosa (Jap. Itabo-Gaki).

These shellfish are useful for food and for various industrial purposes. The oyster, *Avicula martensii*, *Arca granosa*, *Mactra sulcataria*, and *Cardium japonicum* are cultivated in various parts of Japan. Canned oysters are prepared in Hiroshima and Hokkaido. Price per dozen yen, 1.50.

The *Trigonella* is also canned, and has the same value as the oysters.

CRUSTACEAN FISHERIES.

Shrimps, lobsters, prawns, crabs, and other kinds of crustaceans are taken by the Japanese for food. Chief among the economic species are the following:

Palinurus japonicus (Jap. Ise-Ebi).
Peneus canaliculata (Jap. Kuruma-Ebi).
Peneus ensis (Jap. Shiba-Ebi).
Palæmon longipes (Jap. Tenăgă-Ebi).
Palæmon sp. (Jap. Numă-Ebi).
Squilla oratoria (Jap. Shăko).
Mysis sp. (Jap. Ami).
Porhenas pelagicus (Jap. Gazami).
Lithodes camschatica (Jap. Ibara-Gani).[§]
Inachus sp. (Jap. Taraba-Gani).
Grapsus japonicus (Jap. Mokuza-Gani).

Besides these there are still many other species of shrimps and lobsters in Japan. They are all used for food or bait, and are economically very important. *Palinurus japonicus*, or the spiny lobster, lives on stony bottoms of the Pacific shores washed by warm currents; but the other species are mostly found in bays, and prefer sandy or muddy bottoms. They usually hide themselves during the day, and go out in search of food at night

The spiny lobster is caught with gill nets, while the other smaller forms are caught either with trawls or flat-nets, or with traps.

The lobster trawl is a hempen net extensively used in the Inland Sea, and closely resembles the trawl for catching soles already described. The only points of difference are the comparative lightness of the weight used and the stem of bamboo used for keeping the mouth of the trawl open. The former circumstance is due to the fact that this trawl is used on muddy bottoms. The purse is about 14 feet long, and the wings are about 18 feet in length. The meshes are a little less than half an inch in the posterior part of the purse, and from half an inch to a little over five-eighths of an inch in the remaining portion. The drag rope is from 300 to 400 feet long. This trawl is worked under a good wind, and two or three are usually attached to a single boat containing two men.

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[*] *Tako* = cuttlefish, changed into *Dako* when compounded with a prefix.

[†] *Kai* = shellfish, changed into *Gai* when compounded with a prefix.

[‡] *Kàki* = oyster, changed into *Gàki* when compounded with a prefix.

[§] *Kani*=crab, changed to *gani* when compounded with a prefix.

The lobster gill net is a hempen net sunk to the bottom for catching the spiny lobster. It is about 35 feet long and only about 3 feet wide. The meshes are 1 or 2 inches. A single boat usually carries two men, and uses several dozens of nettings joined into a single net, to one end of which are then tied a stone and a float. The whole is then sunk in the evening in rocky places 10 to 50 feet deep, and taken out the next morning.

Prawn pots are used in Lake Biwa in the province of Ōmi. They are made of bamboo splints. At the entrance is a funnel-shaped piece with its smaller end projecting into the interior, so that any shrimp that has once entered it can not get out. When being used, dozens of these traps are tied to a long rope, and crushed shellfish (*Corbicula* or *Paludina*) are put within each: then the whole is sunk to the bottom. They are taken out from time to time and the shrimps are caught.

Among the important preparations from this class are canned spiny lobster and shelled shrimp. Canned lobster is made after the manner of the boiled lobster of the Americans: one dozen 1-pound cans cost 1.20 yen. Shelled shrimp consists of the boiled bodies of *Peneus canaliculata* and *P. ensis* which have been deprived of their shells. About 300,000 yen's worth is produced annually. It is one of the chief exports to China.

UTILIZATION OF ALGÆ.

Among the seaweeds found on the coasts of Japan there are several having considerablee conomic value, of which the chief are amanori (*Porphyra vulgaris*), tengusa (*Gelidium corneum*), funori (*Glœopeltis coliformis*), and fukuro-funori (*G. intricata*).

The first named grows near the mouths of rivers in various parts of Japan. It is cultivated on a large scale in the bay of Tokio. About the time of the autumnal equinox, branches of bamboo and of various trees are stuck into the bottom of the sea, and the seaweed is allowed to grow on them, the fronds being cut away from the top as they grow. The alga wholly dies away about the time of the vernal equinox. The article prepared for commerce is known as *asakusa-nori* and is highly esteemed both for food and as a condiment. The weed is but seldom eaten fresh and nearly always is made into thin sheets like paper, and dried for preservation. This is heated over the fire and eaten with broth, or by itself with a little sauce. It is also used for various other culinary purposes. One hundred sheets cost from 50 sen to 1 yen.

The *Gelidium* grows on the coasts of various parts of Japan, on rocky bottoms, at a depth of from about 10 to 125 feet. It grows in clusters and is never found in bays that have no open communication with the ocean. It is said to germinate in early spring and die away in autumn. The best harvesting season is summer. A jelly is made from this species which is largely used both for food and as glue. It has also recently come to be used for purifying *saké*, or Japanese wine. Added to the already large demand for home use, its exportation has recently increased. In 1891 the exports alone amounted to 454,000 yen.

The species of *Glœopeltis* are employed in the manufacture of glue. They grow on rocks near the coasts of the warmer parts of Japan. The glue is made indiscriminately from the two species, and is largely used to impart luster and stiffness to various textile fabrics. It is also used for various other purposes, according to which it is refined in various degrees. The price of a single sheet (about 5 feet by 3 feet) of the most refined form is 50 sen.

THE FISHERIES OF NORTHERN JAPAN.

By K. ITO.

Fish constitutes the chief article of food in Japan, and the fishing industries are necessarily the most important pursuit of the Japanese. It gives employment to 1,654,178 men, and yields $35,000,000. The peculiar features of the country afford every kind of fishing, and a great many varieties of the marine animals and plants are collected and utilized. It is not possible, however, without some previous preparation, for me to enumerate them or to give any account of the methods used for catching and curing them. I will, therefore, limit my subject to the fisheries of northern Japan, or Hokkaido, with which I am more familiar.

Hokkaido, more familiarly known to you under the name of Yesso, is one of the islands constituting the Japanese Empire, and is situated between 40° 21′ and 45° 30′ north latitude. It covers an area of about 319,000 square miles. The fisheries industry is the oldest and most important of the island. I will give a brief description of some of the principal fisheries of the Hokkaido.

First in the order of importance are the spring herring fisheries. The spring herring (*Clupea harengus*) approaches the western coast of the island in tremendous groups in the spring and early summer, and fishing is carried on from the first part of April to the last of June. The implements used for the capture of this fish are of two kinds—the gill net and the moored trap net. The fish caught are gutted, and the bones and head taken off and dried upon the scaffoldings. They are then made into bundles and sent to the southern part of Japan for food, while the roes, which are left, are dried on the flake or pickled and used for food. The head, bones, and gills left, after making the boneless herring, are also dried and used as fertilizers. But since the introduction of traps, about thirty years ago, and also the introduction of the pocket attachment, after that, the catch became so enormous that all the fish caught could not be utilized in the old way, and so the guano and the oil industries were inaugurated. This industry has grown from year to year and at present is the most important of the fisheries of Hokkaido. At present the total amount of the dried scraps manufactured reaches the enormous quantity of 90,000 tons.

Next in importance is the salmon fishery. Our salmon belongs to the same genus as the Pacific coast salmon. There are two principal species of salmon, namely, the spring salmon (*Oncorhynchus perryi*) and the fall salmon (*Oncorhynchus haberi*). The spring salmon ascend the waters for the purpose of spawning in the months of May and June, and the fall salmon in the late fall months. The fall run is the more numerous of the two, but inferior in flavor.

The methods used in the capture of this fish are several, but the principal kinds of nets used are the drag seines, traps, and gill nets in the seas, while only the drag seines are used in the rivers. Some of the chief salmon rivers in the island can still compare with any salmon rivers in this country. The most important river for salmon is Ishikari, emptying into Strogonof Bay, on the western coast. Curing in salt used to be the only way of preparing salmon for the market, but about eight years ago the Government employed Mr. Treat, of Eastport, Me., to introduce the method of canning; the new industry is growing constantly, and some of the articles are now sent to France. About three years ago a gentleman commenced a smoking business there, and this we hope will soon become one of the principal industries in the salmon fisheries.

Now, I will make a few remarks on the cod fisheries. The cod are most abundant in the winter and early spring. The fishing-ground at present is limited more to the inshore, being from 5 to 25 miles from the shore, and in water from 100 to 200 fathoms deep. The gear used for capture is the trawl, exclusively, the construction of which is on the same principle as the trawls used in the New England fisheries of this country. The vessel used in this work is very small. It is an open, flat-bottomed boat, about 36 feet in length, and is furnished with a single mast and one large, clumsy rectangular sail. The most common method of treating the cod is to take off the head and bones and dry them very hard, like the Norwegian stockfish. The second way is to split and thoroughly cure them with salt. Still, some of the fish of the early catch are just gutted, slightly cured, and sent away for more immediate consumption.

Another important fishery is the iwashi (*Clupea melanosticta*), a kind of herring that comes into the open sandy beach of the eastern coast in the months of June and July. The schools are not so large as those of the spring herring, and are sometimes mixed with "seven dots" (*Etrumeus micropus*) and also with the young of the spring herring. The principal contrivance for the capture of this species is the drag seine. The fish are all made into scrap and oil.

Next, I will mention the trepang fisheries. Trepangs, or sea-cucumbers, occur in the sandy bottom of the sea, all along the coast, and are gathered by use of a dredge. The fish caught are gutted and boiled in a decoction of mugglewolts, or artemesia, and are then spread on a sort of cleat, with bamboo bottom, and dried for exportation to the Chinese market.

Another fish for the Chinese market, and of great importance, is the awabi. The awabi is a gigantic gasteropod, which is known on the Pacific coast of this country as "abalone." It is speared from an open boat, just like the dories used by the New England cod fishermen, in water from 2 to 4¼ fathoms deep. The fishermen formerly used cod oil in order to look into the bottom of this deep water, but water glass is now almost universally used for this purpose. About five years ago some adventurous fisherman introduced the diving apparatus, but, in consequence of its injurious effect upon the propagation of the shellfish, it was finally prohibited by legislation. The fresh product of this fish is separated from the shell, cooked, slightly smoked and dried, and then sent to the Chinese market.

Next comes the squid, which has its run in the fall, lives in big schools, and is caught with the jig. It is split open, pressed, and dried, and sent over to China.

Another product of the sea I would like to mention is the *kombu*. The *kombu* is a kind of algæ, belonging to the species of *Laminaria*. They occur in great abundance all along the coast, but the best kind is obtained on the northeastern coast, where the cold current comes down from the north. They are taken from the rock upon which they grow by the use of the wooden hook; they are then dried on the sandy beach, made into bundles, and exported to China.

Now, let me say a few words in reference to the fishermen on the island. They are divided into three classes: (1) outfitters; (2) fishery proprietors; (3) employés. Outfitters are those who furnish the fishing gears, or capital, or food supply to fishermen who can not fit out for themselves; the fishery proprietors are those who own the fishing vessels, fish-houses, and all fishing gears; the employés are those employed by the fishery proprietors for the prosecution of the fisheries. Some of the fishing is done on shares, like the cod fishery of this country, while others are part in shares and part in wages, and in some cases certain parts of the entire catch are given to the gang of employés, besides regular wages.

The fishermen of my country are a very open-hearted and frank set of people, and are sometimes superstitious. Among the fishery proprietors there are a great many well-educated, intelligent, and progressive men. They have formed associations there for the purpose of preventing the manufacture of inferior articles and to adjust any disputes arising between fishermen. They have a fishery society there, under the name of Hokusui Kyokwai, for the promotion and improvement of the fisheries. They publish monthly reports and distribute among the fishermen important and useful information in regard to the fisheries. They also publish the translated account of valuable information from this country. I think it will be of some interest to you to know that a recent number of a publication which I have received contains a translation of the paper read before the Fishery Convention in London, by one of your prominent members, Dr. Goode. This society holds fairs for competing in the kind of artilces manufactured by the different fishermen.

Now, I will say a few words in regard to the measures adopted by the Government for the promotion of the fisheries on the island. Under this head there are only a few laws for the protection of salmon. The principal features of the legislation protecting salmon is that no stationary apparatus is allowed in the river, and the only kind of net allowed is the drag seine. The next feature is that all nets must be taken out of the water from sunset to sunrise; that is, every night they must cease fishing. The next prominent feature is that fishing of any kind is prohibited in the spawning tributaries, and during the spawning season the Government appoints fish wardens to protect the fisheries from the poachers. In addition to this legislation in regard to salmon there is also a law, which I have already mentioned, against the use of diving apparatus for the capture of awabis.

Next, let me refer to the measures adopted for encouraging the fishermen. The Government has a fund which is loaned to the fishermen when they meet a bad season and when they can not borrow the capital to furnish their outfit. The Government also exempts for a certain length of time from the fishery tax all those fishermen who open new fishing-grounds or who make new fishing establishments, wherever it is impossible to make them without the expenditure of large sums of money.

Lastly, let me just touch on the legislation for regulating the fisheries. Under this head I may mention the method which has been adopted by the Government to govern all fishing-grounds. In every fishing locality, the position of all traps and seines is located on a map, and this map is filed in the county offices for the reference of fishermen, so that when they have any quarrel in regard to the position of nets it can be settled very easily. Under this head comes the regulation for inspecting the manufacture of *kombu.* The manufacture of *kombu* lately became inferior, and to check this evil the Government has made a regulation requiring that all kinds of *kombu* must be inspected and branded before it is exported, just as the mackerel are branded in this country.

Now, before I finish my remarks, let me read a few statistics concerning the fisheries of the island, which I prepared some time ago for the U. S. Fish Commission Bulletin:

Number of persons, boats, seines, and nets engaged in the fisheries of Hokkaido in 1884.

Items.	Hakodate district.	Sapporo district.	Nemuro district.	Total.
Fisheries proprietors	3,218	3,324	1,338	7,880
Employed hands	17,440	33,630	14,703	65,773
Boats	15,100	16,800	3,473	35,373
Seines	496	267	326	1,089
Trap nets	935	1,828	335	3,098
Gill nets	150,820	33,365	65	184,250
Miscellaneous nets	6,406	40	65	6,511

Value of the principal fishery products of Hokkaido in 1884.

Fishery.	Hakodate district.	Sapporo district.	Nemuro district.	Total.
	*Yens.**	*Yens.*	*Yens.*	*Yens.*
Herring	1,412,762	2,023,883	108,003	3,544,648
Fall salmon	31,389	221,993	281,874	535,856
Spring salmon	1,528	5,617	118,675	125,820
Cod	16,396	85,048	712	102,156
Iwashi	116,577	15,434	1,640	133,651
Trepang	5,661	23,210	14,623	43,494
Ear-shell	25,818	95,123	....	121,941
Squid	35,250	2,817	....	38,067
Kombu	49,993	189,811	164,440	404,244
Sea otter	....	....	3,150	3,150
Oyster	....	....	13,413	13,413
Total	1,696,974	2,662,936	706,530	5,066,440

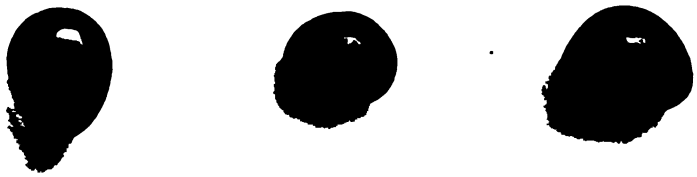
*One yen equals about 80 cents.

I will remark here, however, that the figures just given are rather smaller than the average, on account of the poor catch and low prices during the year; but I think they will give an idea of the amount of the fish caught on the island.

PLATE 18.

FRESH WATER PEARLS, Tennessee.
2 Diameters.

GRAY AND BLACK PEARLS, Lower California.
Natural size.



BLACK PEARLS, Lower California.
2 Diameters.

CLAM PEARLS, Long Island Sound.
2 Diameters.

A Hoen & Co Lithocaustic Baltimore

46.—ON PEARLS, AND THE UTILIZATION AND APPLICATION OF THE SHELLS IN WHICH THEY ARE FOUND IN THE ORNAMENTAL ARTS, AS SHOWN AT THE WORLD'S COLUMBIAN EXPOSITION.

BY GEORGE FREDERICK KUNZ.

In these pages I have sought to bring together a series of notes from the World's Columbian Exposition, regarding the exhibits of pearls and pearl-bearing shells to be seen there, and the various ways in which these beautiful materials have been or may be employed in jewelry proper and in other of the decorative arts, such as inlaying, cameo work, and the like. With these are included some notes upon the use of pearls by the mound-builders of prehistoric America.

Before proceeding to describe any of these exhibits in detail, it may be well to take a general view of the subject of pearls and pearl shells.

The term pearly is applied strictly only to those shells that are iridescent or nacreous. These are of several families, especially the *Aviculidæ*, to which belongs the true pearl oyster, *Meleagrina*, in its several varieties mentioned further on, and the *Unionidæ*, or fresh-water mussels, found in all countries of the globe, but especially abundant in the interior river system of North America. These two latter groups furnish the greater part of the pearls of commerce, while most of the mother-of-pearl is from the shells of the first-named family. Other pearly shells, more or less employed for ornamental work, are the *Nautilus*, the *Turbo* family, the *Trigonia*, and particularly the *Haliotis* family, or abalone shells, which furnish the green mother-of-pearl used with such fine effect for inlaying, etc., in connection with the usual white variety.

Other groups of shells also yield pearl-like concretions or are used in the ornamental arts; but not being iridescent or nacreous, they are not properly pearly, and their beauty is that of color effects simply. Such are in particular the large marine univalves commonly known as conchs. Of these, the pink conch of the West Indies, *Strombus gigas*, is used to a small extent for cameo work, and largely for the beautiful pink jewelry carved out of pieces of the shell, to form brooches, earrings, etc., and cut into bead forms in imitation of the rose-colored pearl. The cameo-shell proper, or king-conch, *Cassis cornuta*, is of a wholly different family, and its white and brown layers afford the finest material for shell cameos. All these and various other colored shells are used also in mosaic work.

I shall take up the subject of the Columbian exhibits in about the following order: (1) Pearls and pearl jewelry, with further notes upon fresh-water pearls, and also upon ornamental articles of which pearls form a part, as shown in the German section; (2) pearls from the prehistoric mounds of the Mississippi Valley; (3) shell carvings, cameos, and inlayings, in many forms; and lastly, remarks on the Unio shells of our own and other countries, as exhibited at Chicago, and their actual and possible uses for ornamental work.

At the Tiffany Pavilion in the Manufactures Building there was a collection illustrating the occurrence of pearls and the various pearl-bearing shells and mollusks—notably a series of several thousand odd-shaped and curiously-formed pearls, pearl blisters, and hinge pearls, from the Unios of Wisconsin, Texas, Tennessee, and Ohio. In this collection are found round, oval, oblong, and mallet-shaped Unio pearls; two pearls ingrown into one another; pearls consisting of scarcely more than a blister, others formed of a single nacreous layer, with a central arc of clay, and other curious and abnormal growths, of interest to the naturalist, but of little commercial value (*see* Pl. 31). A silver tea-pot incrusted with fresh water pearls (*see* Pl. 28). A specimen of the fresh-water mussel *Margaritana margaritifera*, from the Botova River in Bohemia, carefully prepared and injected, showing a pearl in place between the mantle and the shell (*see* Pl. 41). A series of Unios from the Sugar River, Wisconsin (*see* Pls. 35 and 36), and from Texas, Tennessee, and Kentucky, remarkably large; a heart-shaped pearl, very nearly an inch in length (*see* Pl. 31), from the true pearl oyster of Ceylon, interesting as being hollow throughout. (This type has been frequently observed, notably in a collection of this kind presented by Mr. M. Lowensten to the Imperial School of Mines at St. Petersburg.) A pearl oyster was shown with a parasitic fish, *Fierasfer*, from Lower California (*see* Pl. 32); a pair of pearl-oyster shells remarkable for their size, weighing 151.35 ounces (*see* Pl. 37), from the west coast of Australia; a pearl-oyster shell from Tahiti, having attached to it three forms of coral, one of them a group 8 inches in height and 8 inches in width; the mollusk had lived, notwithstanding this great burden, although one of the corals at the side had very nearly suffocated it by closing the shell of the animal at the time when it was captured (*see* Pl. 29). A shell found on the coast of New Guinea had on it a cup-shaped coral over 8 inches in diameter and 6 inches in height. (For a series of similar specimens, *see* Pl. 30.)

There are also other examples where pearls are imbedded in the shells themselves, and some (*see* Pl. 34) where pearls had been imbedded and dropped out; also abnormally large growths in the shell (*see* Pl. 33), some of them more than an inch in diameter and an inch in height. These forms are frequently cut over and used as baroque pearls. Another form is a curious inclusion at the point of the shell, where the muscles are attached to the valves. This has the appearance (*see* Pl. 33) of the eyes and mouth of an ape's head. A small piece of the true mother-of-pearl shell two-fifths of an inch in length, which broke while undergoing the operation of being made into a button, revealing a small inclosed crab (*see* Pl. 32) immediately below the blister; a collection of pearl blisters assuming imitative shapes; and a large pearl-oyster showing the perforations of some marine borer which the mollusk has covered (*see* Pl. 39).

Other exhibits in this series were a group of four pearls united in a heart-shaped form (Pl. 31, E); several hundred pearls from the abalone shell, *Haliotis rufescens*, from the Gulf of California; a collection of various species of Haliotis, one containing an immense interior growth resembling a camel's head (*see* Pl. 38), due to some external injury (measuring 2½ by 2 inches); a collection of fine pearls from the large pink conch of the Bahamas, *Strombus gigas*, varying from deep pink to almost pure white, one of the pearls measuring nearly an inch in length; one small conch pearl and the shell in which it was found, from the coast of Florida; pearls from the Unios of Weymouth, Nova

Scotia; seven of the pearls from the original find made in 1856 at Notch Brook, near Paterson, N. J. (these were from the collection of Prof. D. S. Martin, of New York, where they had been since a short time after the discovery); a small quantity of pearls taken from the altar of the Turner group of mounds, Little Miami Valley, Ohio (these were from the original find of Prof. F. W. Putnam, who obtained several bushels of them, resembling strikingly those found by Warren K. Moorehead at points to be noted further on); a round white pearl, measuring four-fifths of an inch in diameter, from the giant oyster, *Ostrea singaporica;* about thirty pearls varying from white to pink, brown, purple, and almost a deep black, from the common clam, *Venus mercenaria*, from Long Island Sound and Chesapeake Bay; eight pearls from the common oyster, *Ostrea virginica*, from Long Island Sound and the Connecticut coast, one of them over half an inch in diameter and remarkable for its resemblance to the human eye; also the shell and pearls of *Venus fluctifraga*, San Diego, Cal., and *Pachyderma crassatelloides*, and shells and pearls of *Trigonia pectinata*, from Australia.

The most remarkable exhibit of pearl jewelry that was ever seen in this country is that in the four necklaces displayed by Messrs. Tiffany & Co., which for their purity of color, fine orient, even form, and careful selection are unsurpassed—notably a necklace of 3 strands consisting of 159 pearls, weighing 2,038 grains, and a single strand of 44 pearls, weighing 946¾ grains; these strands represent $100,000 each. Possibly more remarkable still for their great size were the strand of 38 pearls, weighing 1,064 grains, valued at $200,000, and the one of 52 pearls, weighing 1,145½ grains, valued at $80,000.

A remarkable illustration of the delicate manner in which pearls can be set is a watch case so thickly incrusted with Tennessee pearls that scarcely any mounting is visible.

Two great French jewelers had very interesting displays; the first, Vever, had several fine necklaces of pearls, notably one 5-strand necklace, valued at about $100,000, and some very large single pearls and various others; the second, Boucheron, had two magnificent black-pearl earrings, weighing about 80 grains each, and several strands of fine white pearls of very large size.

In the French section were also some very fine exhibits of imitation pearls, notably that of Rutan, who had many strings, etc., of them. Constant Vales, of Paris, imitated the necklace of black and white pearls that belonged to the Empress Josephine and the 5-strand necklace of the Princess of Wales. Passeau-Feil, of Paris, had many imitations of both black and white pearls, notably a new kind produced by coating beads made of true mother-of-pearl shell with silver, giving them almost the same specific gravity and the silver simulating the luster of the gray pearl.

Schurman, of Frankfort, in the German section, exhibited a fairly good drop pearl of 105 grains; a remarkable Nautilus shell, mounted in a silver goblet; an ivory figure holding a mother-of-pearl shell; some pearl earrings, of from 25 to 40 grains each, and a quaint brooch, containing a pink, a yellow, a gray, a dark-gray, and a black pearl. Messrs. C. Heitel and Sohn, Hanau, showed a marvelous display of large oriental pearls of great size and fanciful forms. These were baroque pearls, artistically mounted, forming the principal features of figures, paperweights, brooches, pins, coupes, vases, cups, etc., as described hereafter (*see* Plate 19). Among these was a group of historical and other figures of fine artistic finish and original design, made in the style of those of Dinglinger in the Green Vaults at Dresden. The mounting of the figures is in sterling silver, partly gilded and enameled, all on marble or lapis-lazuli bases, with the exception of the first two, which had bases of sterling silver gilt. Some of these were—

A negro king, with white waistcoat formed of a monstrous oriental pearl of good white color, 37 mm. × 29 mm, somewhat pointed on the upper part issuing from the neck and ornamented with 3 rose diamonds; the coat is of blue and yellow enamel, ornamented with 6 more rose diamonds and *en cabochon* rubies. The lower part of the negro's body and head are formed by one large baroque pearl, with the arms and legs of variously colored enamel.

A negress, with bust of one enormous pearl of 20 × 17 mm., narrowing toward the waist, valued at $145.

A dancing girl, the upper part of whose body is formed by a black pearl 25×10 mm. The figure stands on a slab of rose onyx resting on a base which is richly ornamented with gold, silver and enamel.

Mercury, after Giovanni di Bologna. The body and upper parts of the legs of this figure are formed of an oriental baroque pearl, 24×24 mm., going all around the body. One foot stands on a rock, an oriental pearl 22×17 mm., and this again rests on a jeweled stone pedestal.

Don Quixote, Falstaff, a monk, and a hall porter, conceived in artistic mountings, rivaling in delicate workmanship the prototypes of Dinglinger, and not inferior in skilled technical execution.

A goblet with boar's head; the latter, at the end of the horn-shaped goblet, is an oriental pearl of extraordinary dimensions, being over 45 mm. in length and width.

A paperweight; an amourette riding on a dolphin, formed of an oriental pearl 65 mm. in length and 45 mm. in width, pointed at its end.

A sheet of water formed by a very flat pearl 65 mm. in length and 50 mm. in breadth.

Other fanciful conceits, all unique in form, as brooches, dogs' heads, spiders, beetles, pigs, ducks, pheasants, peacocks, etc., the special feature always an irregular pearl. These mounted objects ranged in value from $135 to $1,700.

The firm of Michel Piscione, in the Italian section, had a quantity of the small shells of *Trigonia pectinata* mounted in brooches, as single valves or two single valves together, generally with a fresh-water pearl set in them; and in the Japanese building was a collection of pearls from the abalone shell and various other shells and shell work.

The great family of fossil shells known as the ammonites, and their allies, which are very closely related to the modern pearly Nautilus, were, like the latter, highly nacreous, and in many cases retain this feature very beautifully in their present fossilized state. If the outer layers have been removed by partial decomposition, the pearly layers are exposed as is done artificially by means of acids in "cleaning" Nautilus shells for ornament. Some of the ammonites and baculites of the Cretaceous deposits of Dakota and elsewhere are gorgeous and glowing in their nacreous coloring, in some cases resembling masses of opal, and more rich than any other pearly material known. Specimens of these are not uncommon in geological collections, and some fine examples were shown in the South Dakota State building at the World's Fair.

In this connection may be mentioned some remarkable specimens of *lumachelle* (fire marble) from Bleiberg, Carinthia. One of the finest examples of this beautiful marble was that in the National Museum collection in the Government building; one of the finest-worked specimens was an eighteenth century snuff-box in the Tiffany

Pavilion. This rare and elegant material, nearly all found during the latter part of the eighteenth century, is a limestone filled with fossilized shells, in which the colors have become so splendidly intensified that it is frequently difficult to decide at a glance whether a cut specimen is a fire opal from Mexico or *lumachelle* marble.

Pearls were used in large quantities by the prehistoric tribes of America, and have been found in great numbers in the tumuli of the Scioto and Miami valleys in Ohio. Prof. F. W. Putnam, of the Peabody Museum, Cambridge, Mass., and Mr. Warren K. Moorehead, of Xenia, Ohio, have made extensive explorations in these mounds, some of the results of which were shown at the World's Fair. The former had investigated particularly the Turner group of mounds in the Little Miami Valley, the latter the Hopewell group in Ross County, near Chillicothe, on the North Fork of Paint Creek.

In the Anthropological building was shown the great "find" of pearls made by Mr. Moorehead in the Effigy mound of the Hopewell group. Here more than a gallon of pearls was obtained with two skeletons. They ranged from the size of a small millet-seed to a diameter of two-thirds of an inch, or even more. In shape they were usually irregular, though many were round or nearly so; but the absence of the elongated and hinge pearls is remarkable. All have been drilled, with holes varying from 1 to fully 3 mm. in diameter, but generally the larger size, made with a heated copper wire, in the manner described by early travelers as common among the Indians. This drilling was undoubtedly for the purpose of attaching them to clothing or belts, as shown by the fact that four or five hundred had been originally sewed upon a rough cloth shirt extending from the waist to the knees of a skeleton. Copper plates on the hips had preserved traces of the cloth, and several dozen beads were found with cloth fiber still extending through the perforation. Pearls were usually placed at the wrists, on the ankles, around the neck, or in the mouth. In the Porter mounds at Frankfort, Ross County, several hundred were on copper plates. Nearly all, however, are found loose, although some are imbedded in a hard, rock-like mass of clay, cemented either by a calcareous solution from the weathering of the pearls or by an iron oxide produced by the decomposition of the meteoric iron ornaments that were found in such quantities in the Hopewell group of mounds. These, like all the pearls found in mounds in the Ohio and adjacent valleys, were undoubtedly from the Unios, which were evidently very plentiful at the time these were collected. Very few of the pearls have retained any of the original orient, although it is possible that by peeling them some good unaltered pearl surfaces could be obtained; but it is more likely that either heat or burial in the ground, where they have undoubtedly lain for centuries, has destroyed them by infiltration of surface waters through the earth in which they were imbedded.

In the explorations in which Mr. Moorehead has been engaged, he has found over forty bear's teeth in which pearls had been set, lying near skeletons. The settings were in the side or near the base (root) of the tooth. Skeletons accompanied by a large number of pearls always have other relics associated with them, such as native copper articles, mica, obsidian, galena, hematite, ocean shells, bad-land fossils, and other foreign objects. This fact would indicate clearly that the remains thus distinguished must have been those of prominent persons.

From the altars or "hearths" in mounds have been taken thousands of spherical pearls. For instance, at the Turner group in the Little Miami Valley, Prof. Putnam, exploring for the Peabody Museum, secured half a bushel, nearly every one blackened by heat, some cracked, and all impaired in luster. Mr. Moorehead took from two hearths upward of 100,000 pearls.

In an altar, or "hearth," of the Effigy mound were found a number of bears' teeth and several quarts of pearls, many of which had several successive layers flaked off. Some of these pearls measured two-thirds of an inch in diameter. In this remarkable altar were found hundreds of obsidian knives and spears, of exquisite workmanship, measuring from a few inches up to 8 inches in length. With these were several hundred earrings made of native copper coated with meteoric iron.

From their manner of occurrence in connection with the skeletons, the archæologist is led to see that the use of pearls, although so many are found, was confined to a few individuals.

A remarkable fact in this connection is that pearls have never been found in isolated mounds, nor out of the great mound groups. The hill mounds, the villages of the small streams, and the tumuli of northern Ohio have yielded none. They seem to have been used by the more cultured tribes, and are an evidence of extensive trade and barter.

It is of interest to archæologists to note further that they are not found in any quantity outside of the Miami and Scioto valleys, and that they invariably were kept in large and prosperous communities; that the pearls were deposited with the remains of persons held in especial distinction; while the enormous numbers found indicate that the yield of Unio pearls must have been far greater in the remote past than it has been at any time since the whites have occupied the country.

From Taylor's mound, Oregonia, Warren County, Ohio, there were four Unio shells in which a hole two-thirds of an inch in diameter has been drilled, either for the purpose of extracting a piece of the shell to make a bead from, or else to allow the shell to be used as an ornament. From this same mound were shown decorated disks made of Unio shells, and a long Unio from which the corner nearest the lip has been either ground down or cut off, evidently to adapt it for use as a scraper or a tool of some kind.

In the Ayer collection from Alaska was a large cloak of buckskin decorated with about one hundred pendants of abalone shell (*Haliotis kamchatkana*), the exterior of the shells being almost a brick red, the interior showing a brilliant iridescence of green, red, and yellow, the combined colors making a pleasing contrast with the dark-brown buckskin. The pieces are pear-shaped or elongated, frequently with a square lower end, occasionally having a notched edge, and varying in length from 1 to 4 inches.

One of the most striking objects in this collection was an ornament made of walrus bone, beautifully inlaid with green abalone shell. The shape is that of a capital letter H, laid down horizontally, the sides being concave and curving gracefully. The length is about 5 inches and the breadth 1¼ inches at the middle and nearly 2 inches at the ends. The whole is adorned with elaborate inlays of abalone, oval, semioval, ring-shaped, etc., producing a delightful combination of color in contrast to the yellowish-white bone.

The decoration of various wooden dishes, bowls, boxes, and chests with pieces of abalone shell, is striking. Many of these are remarkably beautiful; and when it is considered that they were used as household utensils, one can not but admit that these savage tribes possess more natural artistic taste than nine-tenths of our American people. They also used circular pendants, either plain or with serrated edges, and in several instances engraved with a human eye, the outlines being filled in with a red mineral color. Abalone or Haliotis shell is also skillfully used in the decoration of their horn spoons, the handles, quaintly carved, being inlaid with abalone and Unio shell.

In the Emmons and Terry collections in the anthropological gallery of the American Museum of Natural History, at New York, are some remarkable specimens of pearl work from the aboriginal tribes of Northwest America. Among these may be noted some of the grotesque masks of the shamans, or medicine men, of the tribes of British Columbia, in which the face is surrounded with large inlaid pieces of Haliotis (abalone) shell. Another exhibit shows the whole process of making pearl fishhooks, among some of the Pacific coast Indians. Pearly shells are cut into rude disks of about 2 inches diameter; these are then perforated and the perforation gradually enlarged until the disk is reduced to a flattish oval ring; this ring is then cut through on one side, and worked into the shape of a letter C, and the completed hook is soon attained. Another consists of several hundred ring-shaped and discoid pieces of pearl, averaging from 1 to 2 inches across, which were found together in a grave in California. These are further drilled with small holes on opposite edges, evidently for sewing them to a garment, doubtless a splendid pearl-covered mantle worn by some distinguished person and buried with his remains.

The South American exhibits presented many interesting uses of pearly shells, both for inlaying and in various forms of personal adornment. Both these modes of application seem to have been carried very far among some of the native tribes of this continent, as indicated by the articles here described, nearly all of which are now in the Field Columbian Museum.

In the Amazon basin the Unio family is well developed, but is largely represented by two genera not found elsewhere, *Castalia* and *Hyria*. These are characteristic South American types, and while differing from the Unios and Anodons of North America and the Old World, are equally suitable for ornamental uses, from their pearly character. Probably many of the objects here described were made from these shells.

In the Paraguay collection were a number of necklaces made of oblong squares of Unio shell, connected by means of a fiber drawn through two drilled holes at the upper end, while the lower ends are decorated with three small circular drillings which do not entirely perforate the shell. Another necklace consisted of small joints of hollow reed or bamboo, about an inch in length, between which were blue-glass beads, and pendent from each of these a small brilliant Unio shell, pure white, with a slight iridescence, and remarkably beautiful. Still another necklace was made entirely of Unio shells, not very iridescent, with the dark-brown epidermis remaining on the exterior. Internally the drilling was either near one of the ends or toward the center of the shell. These were strung by a thin vegetable fiber so as to hang pendent about 3 inches from the fiber necklace, and were evidently intended to serve for a rattle or noise-producing ornament. In the same exhibit were a large number of pendants, consisting of small pieces or large sections of Unio shells, beautifully iridescent, varying in form from oval to disk-shaped, and in length from 1 to 4 inches. In another necklace Unios were strung indiscriminately with hoofs of some small animal.

The use of shells as ornaments is very pronounced among these people. In addition to those mentioned, Bullas and land shells were strung in a similar manner. These were white, gray, yellow, frequently with pink-tinted tips. An interesting necklace consisted of operculums, 2 inches in length, of some large shell, attached by a fiber decorated with yellow feathers.

From Peru, life-size models of the Zaperos and Jiveros Indians, residing on the Montaña of Peru, were shown fully attired with their ornaments. These tribes decorate their headdresses, shoulder bands, and breasts with a profusion of circular, diamond-shaped, and pear-shaped pieces of a brilliant Anodon shell. These they arrange to form stars and other patterns, by sewing a number of them to the fabric, generally by means of perforations, and frequently have them swinging as pendants from the dress. They also use small Unio shells, the wing-cases of beetles, white and red dried seeds, teeth of animals, etc.

A woven necklace on which are sewed square sections of some fresh-water shells, and hanging from it oblong pendants; also three shells of the Spondylus, a pendant ornament, the red color of the latter shell adding a very striking feature.

From Peru, was shown an immense mother-of-pearl casket measuring 30 inches in length, 17 inches in width, and 18 inches in height, ornamented with large silver clasps and handles, and decorated with scrolls filled with a black pitchy substance, probably asphalt, Spanish work dating from the sixteenth and seventeenth centuries.

In the collection made by Dr. O. Finsch, of Hamburg, Germany, from the islands of the Pacific, are a number of shell articles, naturally much used among a people whose choice of materials is so limited and whose life is so much upon the sea and beach. Among these may be mentioned: Fishhooks and scrapers of mother-of-pearl, from the Caroline Islands; armlets from cross sections of *Trochus* shells, from New Britain; similar armlets from New Guinea, decorated on the exterior with characteristic carvings; also nose ornaments, tassels for earrings, etc. The nose rings were in shape long-elliptical, about 3 inches by ¾ of an inch, with a piece cut out from the middle of one side, about ½ inch in length. This interrupted ring could then be put on the lower part of the nose, and would remain there by clasping it, much as we attach our spring eyeglasses above. Some of them were carved and some plain.

Another New Guinea ornament was a sort of plate or gorget, oval in form and about 3 inches by 2, perforated at the middle of one side, to be suspended and worn. This was cut so thin as to be almost transparent.

A somewhat similar mother-of-pearl gorget, from New Britain, about the same size, has the form of a semi-ellipse, with the upper edge cut somewhat concave, so as to give the whole a lunate shape. At the middle of the concave side are two drilled holes near together, to suspend it.

In the Orient articles of personal adornment made of shell have been used and valued among the East Indians time out of mind; particularly, bracelets made from large univalves, such as *Turbinella rapa*, have been regarded as indispensable by Hindoo women, and worn as a badge of ceremonial purity by every wife. They are given to the bride by her father at her marriage, and a brief religious form is gone through before putting them on.

In making them, the shell was cut into thin slices, as it were, across the body-whorl of, *e. g.*, a large *Turbinella*, and these were then easily wrought into rings of a suitable size for bracelets. They were then variously ornamented by gilding and coloring, or attaching beads, etc. Their use, however, is gradually becoming less general. Many varieties are made, distinguished by different native names, and a series was shown in the Indian Department of the International Exhibition at Glasgow, in 1888. The prices are very moderate, ranging from an average of half a rupee to a rupee for a pair.

Fuller references may be found in "The Art Manufactures of India," by T. M. Mukhauji, Calcutta, 1888, p. 265.

SHELLWORK AND MOTHER-OF-PEARL IN FURNITURE AND JEWELRY.

Some excellent examples of Damascus inlaid pearl work were those shown by Lockwood DeForest in the Manufactures building (*see* Pl. 23). These consisted of chests, some of which dated from the early part of the century, in which diamond-shaped pieces of mother-of-pearl were set in carved brown wood; also some very fine examples with floral and arabesque designs in mother-of-pearl work. They form a very pleasing contrast when inlaid in the dark-brown wood used throughout the East in making settees, chairs, and other objects of Oriental furniture. These are now regular articles of commerce, and are quite extensively imported into the United States.

Pearl-inlaid musical instruments are not infrequently seen. A number are exhibited in the Metropolitan Museum of Art, New York City, in the Brown and Drexel collections. Among these may be mentioned Turkish and Persian tambouras, etc., inlaid with pearl in dark-brown wood, in the favorite Oriental style—the pearl pieces being mainly lozenge-shaped or in simple geometrical forms. More elaborate patterns are seen in Italian work, particularly in several mandolins of the eighteenth century, in which both bowl and stem are richly inlaid in somewhat peculiar and characteristic forms.

A unique piece of American pearl-work is a mandolin exhibited at the World's Fair, by the makers, Lyon & Healy of Chicago (*see* Pl. 22), which was purchased by the proprietor of the Kimball Opera Comique Company as a present for Corinne. It was entirely covered with inlaid work, four kinds of pearl being employed, of different shades and tints, inlaid in metal. More than 2,000 pieces of the several materials were used, and 255 days' labor expended in making it, in cutting, fitting, and polishing the pieces of pearl. It was valued at $1,500.

Some years ago there was shown in New York City—probably at the old Crystal Palace exhibition—a piano in which the entire keyboard was of pearl, the body of the keys being of ordinary white mother-of-pearl, and the flats and sharps of green abalone (*Haliotis*), producing an extremely rich and pleasing effect.

One of the most remarkable examples of American pearl inlaying was a grand piano made by Cottier & Company, of New York city, which is a study of the old Spanish method of inlaying mother-of-pearl with tortoise shell and colored woods in a hard wood. Plate 26 represents what is probably the most remarkable example of inlaying of woodwork ever made in the United States. This is only one of a number of pieces, all varying in design, marking, coloring and workmanship, that this leading firm of woodworkers and decorators have produced from time to time.

Another exposition piece—an electrolier designed by Mr. Louis C. Tiffany—is inlaid with flowers, each petal formed by one of the natural segments of the chambers of the pearly nautilus (*Nautilus pompilius*), while the background is inlaid with bits of abalone shell.

There may also be mentioned a table in the same exhibit, where the flowers, forming part of a decorative border upon the top of the table, are made of pearl-oyster shell.

Some fine specimens of inlaying in furniture were shown in the Italian section by Ferdinando Pogiani, where mother-of-pearl is used in diamond-shaped and hexagonal forms, in the Oriental manner, as well as for entire figures inlaid with ivory and ebony, as a decoration in connection with his fine furniture.

Among many striking applications of pearl-bearing shells to decoration and furniture may be noted, in particular, some shown by the Tiffany Glass and Decorating Company in the Manufactures Building. One of these, a specimen of high art, is an ecclesiastical table. Beneath the edge of the mensa, or top of the altar, which consists of a single slab of Carrara marble, is a design of four circles, each containing one of the Apocalyptic emblems of the four evangelists. On the altar frontal, on either side of the center, are two larger circles, each containing a monogram of the Holy Name imbedded in a background of rosary beads made from the Fiji Island pearl shell. The monogram is further enriched by inlays of gold and precious stones, and made to appear iridescent by the addition of the green Japanese mother-of-pearl (abalone shell). (*See* Pls. 22 and 24.)

A tabernacle door is beautifully ornamented with several kinds of pearl shell from South Africa and from Terra del Fuego and Japan.

On the walls of the chapel, containing part of the above-named exhibit, the green abalone shells were made to simulate peacock's feathers with wonderful success.

Tiffany & Co. exhibited a very fine piece of work in the dial of a large astronomical clock. This dial measures 20 by 30 inches. The shells are arranged in such a manner as to give sky and sea effects. Inlays of mother-of-pearl shells were also used in elaborate scrolls on some boxes made of shark skin from Long Island Sound and Java, the shark skin being stained green, yellow, and other colors, and polished.

One of the most interesting objects of pearl inlay was a small round earthenware pot in the collection in the Cliff Dwellers' exhibit, immediately west of the Anthropological Building. In this earthen pot, irregular squares of Unio shell (fresh-water mussel) have been inlaid in hard clay in regular layers, the clay between the pieces of pearl being about the width of the pieces themselves, and producing the effect of mosaic. This is the only object so decorated that has ever been found.

Pearl-shell has also been utilized in the beautifying of church vestments. Two varieties have been specially used; one form, employed in the decoration of a miter, is peculiarly adapted to the embroiderer's art, as the protuberances on the true pearl oyster, sawn out and pierced, or mounted in a metal border and pierced, can readily be fastened to the embroidery with silk or wire. The other form is beads made from the Fiji Island pearl shell, which have been successfully used in the decoration of a chasuble. The natural surface of the shell is not ground down; only the sides are shaped, thus giving a more pearly appearance than if the whole were polished. In Russia, for centuries, this method of embellishing ecclesiastical garments has been practiced with wonderful success. The treasury of the Metropolitans in the Kremlin at Moscow contains an immense number. These applications seem a curious "reversion" to the Indian pearl-covered mantle referred to previously, as indicated by the cut pieces of mother-of-pearl in the American Museum of Natural History.

Some of the finest known examples of inlaid pearl work are in the canopies of the the tombs at Allahabad, India. These date from the sixteenth century, the pearl work being a thin veneer set in black wood, and the ornamentation consisting of elaborate Persian designs.

In the Siamese pavilion were numerous examples of inlays, minute diamond-shaped pieces of abalone shell set in a black, pitch-like lacquer. This is similar to the lacquer work that the same people make, in which they use tiny bits of looking-glass made of remarkably thin glass with a coating of mercury on one side.

In the Chinese section there were some fine specimens of what Jacquemart, in his "Histoire de le Porcelaine Chinois," describes as *lacque burgandée*, belonging to the reign of Kong Hi, in the seventeenth century, and made in the porcelain works at Ching-te-chew. They consist of an application of black lacquer on a specially prepared unglazed porcelain, the lacquer inlaid with thin flakes of pink and other iridescent colors of mother-of-pearl. Thin leaves of gold and silver are inlaid and introduced as parts of the decoration. Through time the silver has generally become black. This method of inlaying is now carried on at Canton and in Cochin China, forming quite an industry, wooden vessels and dishes being used instead of the unglazed porcelain.

The embellishing of ironwood, teak, and other wood at Canton forms quite an industry, the shell being set in wood in the form of leaves, flowers, and arabesque designs blending with the carved and plain surfaces of the chairs, settees, and other objects in which the shell work is inlaid.

The Japanese have added to the inlaying process the painting of mother-of-pearl work with lacquers. This work dates from the time of Kovin and Ritzui, the greatest artists in this line, who, although they did not create the art, founded quite a school for this style of ornamentation. The abalone shell is used to represent hawthorn or other floral designs, and the lacquer is brought close to the pearl work, the two blending one with the other, and the pearl itself occasionally exquisitely lacquered. Another form of ornamentation consists in inlaying, into the lacquer, squares of mother-of-pearl, so minute as to form an unbroken iridescence; also microscopic petal-like bits arranged as flowers in transparent lacquers. Beautiful examples of such Japanese work, in various styles, may be seen at the Metropolitan Museum of Art in New York City. In the Moore collection, for instance, is a casket with butterflies in abalone on gold lacquer; another with leaves and flowers in mother-of-pearl, also on gold lacquer; and some small pieces so closely inlaid with pearl that nothing else appears, and the most exquisite effects are produced by the different kinds employed, the ground being a sort of mosaic of the brightest green abalone, and the patterns inlaid in rich pinkish and lilac-tinted mother-of-pearl.

As so little has appeared in the United States concerning the utilization of pearl shells of any kind in lacquer or similar industries, the following notes[*] from the works of Prof. J. J. Rein, of the University of Berlin, and Prof. Christopher Dresser possess great interest:

Ao-gai-nuri or *ao-gai-togi-dashi*, mother-of-pearl lacquer, in which the coarsely or finely pulverized mother-of-pearl from varieties of Trochus and of Haliotis is used. If whole surfaces are to be evenly adorned, the process is like that in which metal powder is employed. If, on the contrary, definitely outlined decorations are intended, stencil patterns of tin foil are pasted on the surface of the groundwork, and the open spaces are coated with *rō iro urushi*, and then sprinkled with ao-gai or mother-of-pearl powder. When dry the patterns are removed, and the whole is coated with a mixture of *ro iro* and *se-shime urushi*, and then the strewn mother-of-pearl is carefully rubbed with magnolia charcoal. A second coat of the same lacquer varnish follows, then a second rubbing, and finally the polishing. The same course is pursued in the simpler work of strewing the whole surface evenly with mother-of-pearl powder. The beautiful green and violet iridescence of small mother-of-pearl pieces on the lacquer wares decorated with it depends on its varying position toward the light and the uneven coating of the transparent lacquer varnish.

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[*] See also article on "Lacquer," by Russell Sturgis, in Johnson's Universal Encyclopædia, vol. IV, New York, 1894.

Shari nashi ji, i. e. *tin (dust) pearl ground*.—The tin dust (or bronze powder instead) is strewn with a little sieve, evenly or in stripes and figures, on the moist coat of naka nuri and when dry covered with a coat of se-shime. With this it takes a brown color, like the scattered powder of a precious metal. The gold ground becomes lighter yellow and more lustrous with age, the scattered tin or bronze dust on the contrary grows darker and duller, as may be easily observed in many of the common Japanese lacquer wares. It is to be understood that the strewing of metal powder does not finish the work, but that a coat of transparent lacquer and the polishing process must follow.

Simple lacquer wares, ornamented with inlaid work.—I rank this group next to the preceding, because its execution, although demanding some skill, does not, any more than the foregoing, necessitate a real artistic talent. The precious metals also are either not at all, or only exceptionally, employed in this. The inlaid mother-of-pearl work, ao-gai zaiku, as cabinets, boxes, dishes, etc., which are brought in such numbers to Europe and made chiefly at Nagasaki, belong principally to this class. It is customary to incrust even the finest lacquer wares with mother-of-pearl, ivory, and precious metals, and to form from them reliefs of flowers and other natural objects.

This branch of lacquer industry is already old, as articles in the Dutch, Dresden, and other collections testify. The common ao-gai comes from the inside of the shell of the Haliotis, each shell yielding only one thin plate. The finer or ma-gai ao-gai, i. e., ao-gai imitation, is the product of the large Trochus and comes principally from the Riu Kiu islands. Both kinds (in Trochus the last convolution) are scaled off in thin, transparent sheets, in a painstaking, primitive way.

The mother-of-pearl sheets are laid on the design, which is pricked through with India ink and brush. The colors (Prussian blue, gamboge, and a mixture of the two for green, also sienna, carmine, carthamine, etc.) are rubbed together with hot glue water and laid on with the brush according to the pattern, on the right places in the mother-of-pearl. When dry, the painted portions are covered with silver foil laid on with glue water and again dried. Then the mother-of-pearl is cut with a sharp chisel into the shapes designated on its opposite side (leaves, flowers, etc.), with their corresponding transparent colors. These are glued [illegible] groundwork of vases, boxes, cabinets, etc., and all the depressions [illegible] black lacquer. Then the whole surface, including [illegible] coats of transparent varnish [illegible] necessary [illegible] The underlying [illegible] pearl from [illegible] the more [illegible] sometimes used [illegible] finish.

Ao-gai-zaiku, mother-of-pearl work.—Pearls and mother-of-pearl consist of thin laminæ of carbonate of lime with a little organic substance. But while they are found in concentric layers in the pearls, in the latter the laminæ follow the direction or trend of the shell, yet in such a way that even in flat mussel and snail shells they lie somewhat inclined to the surface. The luster proceeds from the reflection of light and the iridescence or play of color from the interference of the rays reflected from the projecting edges of the thin laminæ or blades and the somewhat deeper parts. (The color change or iridescence of mother-of-pearl, consequently, is a phenomenon of interference which inheres in the structure, and is analogous to the colors of diffraction spectra produced by ruling very fine lines upon glass plates, etc.)

Furniture inlaid with mother-of-pearl is very popular in Turkey and throughout the entire Orient, but particularly in farther India and China. In Japan it is used mainly for decorating lacquer wares. A product of the country, called ao-gai (awogai), used in thin sheets, is distinguished by its magnificent iridescence in all the colors of the rainbow, and is obtained mainly from the smooth inside of the larger varieties of ear shell (*Haliotis japonica* Reeve, *H. gigantea* Chemn.), called awabi. A still more valuable sort goes by the name of ao-gai-magai, *i. e.*, imitation ao-gai. It is formed of laminæ scarcely 3 centimeters broad, and is said to come from the Riukiu islands, from a kind of Nautilus. The shell of the Sazaye (*Turbo cornutus* Chemn.) also yields mother-of-pearl.

The polishing of the mother-of-pearl, as observed in Nagasaki, is not scientifically conducted, since there is no facilitation of the work such as is afforded by the heavy grindstone, revolving vertically on its axis. The thick, curved outer edge of the Haliotis shell is first removed up to the row of holes, by means of pincers, hammer, and chisel; then the remaining part is ground on a fine-grained grindstone, sprinkled with water, till only a thin transparent lamina remains. It is a very wearisome work, and one man can polish only eighteen pieces a day. Each sheet costs from 2 to 6 *sen*, according to size and fineness. These thin sheets or plates, as well as the mother-of-pearl dust of various degrees of fineness, obtained from the waste, are now used by the ao-gai-shi, or mother-of-pearl workmen, for decorating lacquer wares.

The inlaying of pearl in lacquer * is effected almost exactly as we inlay our papier-mache work, the process differing only in detail. The pieces of pearl from which the parts to be inlaid are cut are very thin, and can be used like tracing paper. Before a work of this kind is begun, a drawing of the pattern is made on a sheet of paper; this drawing is transferred to the box or tray upon which the pattern is to be wrought. Little sheets of pearl are now placed over those parts which are to appear in this lustrous material; the forms covered by the sheets of pearl are traced upon them, and then they are removed. With a curious chisel like knife, the pearl is next cut into the desired shapes, and these are stuck by lacquer in their respective positions. After all are in place, the whole surface is covered with repeated coats of lacquer, by which the pearl is entirely hidden. By grinding, a smooth surface is then secured, and the pearl again appears, but is now level with the general surface. The pattern is again transferred to the surface, having been fitted to the bits of pearl so that they may take their right places.

Besides this raden or mosaic work with thin sheets of mother-of-pearl, thicker pieces are ground and engraved as a flower, an egg, or some other design, and made to serve, like ivory, as an inlay in raised gold lacquer work. The making of brooches out of this material, however, and turning buttons and other articles of jewelry on the lathe, are scarcely known.

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* "Japan," by Prof. Christopher Dresser, page 362.

An enterprising New York firm utilized in a novel way all the available pearl sheets, or leaves, as are termed the paper-like pieces of ear-shell, or *awabi*, as it is called in Japan, where, in preparing the abalone shell for export, they break off the thick edge, or "ear-piece," and reduce the rest almost to the thinness of paper, and then polish. These thin sheets, or leaves, were ingeniously inserted for windows or for sky effects on photographs made on glass, the plates being views of the World's Fair buildings, and were sold in great quantities.

SHELL CARVINGS AND CAMEO WORK.

Among the most beautiful pearl work may be noted the high-relief cameos carved on mother-of-pearl shells, seen in the Italian section and elsewhere. Here advantage is taken of the difference of tint in the inner and outer portions of the dark variety (Tahitian pearl-shells) to cut cameos, where groups of carved figures 6 inches in diameter in white pearl are raised upon a background of darker pearl, producing a peculiarly elegant effect. Cameo work is also shown on the pink conch of the West Indies (*Strombus gigas*), where deeper and paler shades in the shell afford similar opportunity for relief designs. Some magnificent specimens of carved *Cassis cornuta* (queen conch) were in the exhibit of Rocco Morabito, of Naples, who, among other fine examples, had one immense group of figures on a conch, representing scenes in British history. This required two years' work.

The firm Decaro, of Naples, had many remarkably fine cameos, as well as carved shells representing Columbus, Diana, and Neptune. The firm Santa Maria (Rome and Florence) and Michel Piscione showed remarkably fine carved conch shells; and Leopoldo Pelissier had, among others, one depicting the Columbus caravels, another representing the landing of Columbus. The latter has been purchased by Gardiner G. Hubbard, of Washington, D. C. On the other side of the shell is a medallion head of Columbus (see Pls. 20 and 21). Throughout the entire Italian section could be seen many interesting examples of the utilization of the common conch and the queen conch, mother-of-pearl and other shells, into various beautiful articles representing industrial progress.

An interesting exhibit is that of M. Toledo, the work which he terms Massaniello, a lava-like material, surrounding which is a square frame made up of long pieces of the queen conch (*Cassis cornuta*), ornamented with elaborate, delicate, and intricate figures and scrolls in cameo work. This piece is of the highest artistic merit, and was one of the daintiest bits of carved shell work in the Exposition.

The utilization of mother-of-pearl for carving was also well illustrated in the exhibit of Dabdoub Brothers and by that in the Turkish Village. Here the polished mother-of-pearl shells are engraved with allegorical and ornamental designs and are known as Jerusalem shells, serving for trays, light screens, and similar objects. They are also cut into paper-knives, spoons, etc., and rounded into beads and strung to represent pearls, the beads being flat and the original nacreous surface being left to give a more pearly effect. They are quaintly carved into brooches and bracelets. In the Manufactures Building was exhibited a fine crucifix several feet in height, and other interesting objects.

Leitner and Saloman showed a large quantity of mother of pearl shells and a series of works in engraved mother-of-pearl handles, paper cutters, and like objects from Australia.

In the Anthropological Building, forming part of the Ward collection of mollusks, were fine examples of Pinnas from the various parts of the world, four specimens of the pearl oyster, *Avicula Meleagrina margaritifera* Lam., from the Indian Ocean, which are remarkable examples of carving by hand, and some beautiful carved examples of *Avicula macroptera* Lam., enriched with a [illegible] ornamentation; also fine examples of *Avicula hirundo* and *Avicula sterna* Gould.

In the building of the French colony of New Caledonia were [illegible] examples of engraving of mother-of-pearl shells, the relief being [illegible] the cutting with [illegible] [illegible] reproductions of [illegible] steel-plate engravings [illegible] pardoned [illegible] that it has been [illegible]

Another [illegible]

various busts representing the several provinces of the empire. The central group includes eight busts and eight fruit groups which embellish the dish, all the shellwork being placed on a background of lapis-lazuli. This was designed by Professors Storck, Karger, and Schwartz, and executed by Dorflinger & Brothers, Frankfort-on-the-Main.

Another design by Prof. Storck is a frame of Louis XVI style, inlaid entirely in gray, white, and black mother-of-pearl, and pink and yellow conch, 13 by 8 inches in size, executed by Rudolph Furtener, of Vienna. In the same exhibit were a collarette of four rows of mother-of-pearl beads with drops, set in silver and gold enamel; also a necklace and brooch, both designed by Prof. Storck. A collarette of five strands of sea pearls that alternate with panels of silver gilt was designed by Prof. Storck and executed by Bachner & Son, of Vienna. A casket 12 by 15 by 10 inches of ebony, mahogany, and olivewood, decorated with mother-of-pearl, was designed and made by Anton Michel of Vienna.

MISCELLANEOUS USES OF SHELL MATERIAL.

Great quantities of mother-of-pearl cat's-eyes were sold, mounted in silver or some other metal, and many people believed them to be true oriental cat's-eyes. These are generally made out of dark mother-of-pearl shells, abalone, or some other dark-colored species. By cutting across a thick layer of such shell and polishing the piece into a hemisphere the light condenses upon the dome into a band, giving a cat's-eye effect. A number of green Trochus shells were made into napkin rings by cutting oblique sections across the large diameter of the shell, leaving the apex or spire of the shell as well as the main whorl to receive the napkin.

With reference to the imitation cat's-eyes and the cutting of beads, etc., as also other peculiar uses, the following notes may have interest here. They are taken from a consular report on these pearl industries made by Mr. Edward Bedloe, U. S. consul at Amoy.

In the cutting of beads, buttons, studs, and other small articles from shells of a high luster, there are some fifty species utilized, of which the Chinese mussel and oyster are the most prominent. One variety gives a black, blue, or white button, similar to the cat's-eyes of Ceylon, and named after these, Amoy or Canton cat's-eyes. A second variety is of a pale fawn ranging to translucency, called white cat's eyes. A third is half an inch in diameter and resembles light-brown onyx. The black and white cat's-eyes are used for bracelets, necklaces, ladies' dress buttons, and also as dress ornaments similar to pearls. The balls are strung and used as necklaces, bracelets, earrings, and rosaries. Though apparently fragile, they are really tough and very durable. Their price depends upon some inscrutable Chinese rule, and varies from half a cent to 5 cents apiece. When mounted as buttons the black cat's-eyes are a pleasing ornament when worn on a black-silk dress. The gradations of color are brought out into fine relief, and the suggestion of blue, which runs through the shell, gives a color to the somber silk, which is very pleasing. The best effect is when they are sewed closely together in a double line upon a vest or waist, when they seem to be a fine and brilliant stripe. A curious way of setting both cat's-eyes and onyx balls, practiced by the Chinese, consists in alternating them with small carved

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fruit stones. It is rather attractive as an oddity, but the lack of color deprives it of any æsthetic value.

Among the quaint things shown by the Chinese* are the cups, saucers, and spoons made from the larger types of tropical univalve shells. The finest specimens come from the southern Philippines and the next from Borneo, but good ones are found in the Pescadores and Formosa. It would seem as if the original idea was Malayan and that the other races of the Orient were merely imitators. In making cups and saucers the conchs are sawed through in about the same manner as cocoanuts are when intended for dippers. They are cleaned and polished, and the convex surface ground slightly so as to rest on a table without spilling or tilting. The spoons are made by sawing the round superior surface of the conch at such an angle as partially to intersect the spindle or major axis (columella), which becomes the handle of the completed spoon. According to the size of the shell, the result is a dessert-spoon, a tablespoon, or a ladle capable of containing a quart. The interior is of a rich sulphur, salmon, or orange color, or of a pearly luster. It has no angles where dirt can accumulate, and is about the handsomest natural spoon that I have ever seen. They stand heat and cold well, but are attacked by vinegar, lemon juice, and other acids. The best market in which to obtain them is Cebu, in the Philippine Islands.

FRESH-WATER PEARLS AND PEARL SHELLS OF THE UNITED STATES.

The abundance of the pearly shells of the family Unionidæ, commonly known as fresh-water mussels, in all the lakes, streams, and rivers of the United States, makes them quite important as a possible source of material in the ornamental arts. Reference has been made at various points in this article to fresh-water pearls and their use in jewelry, both in this country and Europe, and to the enormous numbers gathered in prehistoric times by some of the mound-builders of Ohio. As we possess so great a variety of these shells, so widely distributed over the country, it seems desirable to bring together here a general review of all the material of this kind shown at the World's Fair, and to lay stress on the value which it may have for decorative work, and the importance of preserving and utilizing the supply so freely bestowed upon our country and hitherto so little appreciated.

Included in the references above made to various exhibits of pearls and pearl shell are the following:

In the Tiffany exhibit in the Manufactures building: The prepared and injected specimen of *Margaritana margaritifera*, from Bohemia, showing a pearl in place between the mantle and the shell; Unio pearls from Nova Scotia; seven of those from near Paterson, N. J., gathered in the first river-pearl excitement in 1856; and some of the prehistoric pearls from the Turner mounds of Ohio.

There was also a large collection of various species of Unios, from the small shells to the magnificent valves measuring nearly 8 inches in length, in a series in which one valve of each specimen is polished and the other in its natural state, to show the commercial possibilities of these shells.

In the museum of the Brooklyn Institute of Arts and Sciences there is displayed, in their local collection of the mollusca of Long Island, a remarkable specimen of

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* Report of U. S. Consul Edward Bedloe, at Amoy.

Anodon, with both valves polished and beautifully pearly, from the lake in Prospect Park in that city. The valves are about 6 inches long. A number of these splendid Anodons have lately been found in this lake, and the fact that they can thus occur shows how readily these mollusks could be propagated and their shells made an article of commercial value.

In the Swedish building, Augusta Mollenberg, the royal court jeweler, exhibited twelve fresh-water pearls, weighing from 4 to 10 grains each, eight mounted on a chalice and two on an ecclesiastical bowl. A Norwegian jeweler exhibited several dozen pearls, white and faintly pink, from Norwegian rivers.

In the English section of the Manufactures building Edmund Johnson, jeweler royal of Ireland, exhibited several fresh-water pearls, weighing over 10 grains each, from Irish rivers, mounted in a brooch in his collection of representations of Irish gold antiquities.

In the Mexican section, in the Fisheries building, from the district of Jederal, with a series of pearl shells from the west coast of Nueva Leon, was another of fresh-water Unios, some measuring nearly 10 inches in length.

In the southeastern gallery of the Anthropological building there were displayed about fifty specimens of Unios and mother-of-pearl shells, with one valve of each shell polished.

In the German section of the Manufactures building, and elsewhere, were shown Unio shells from the Elster, in Saxony, and the Bohemian rivers, frequently polished on both sides and made into beautiful little portmanteaus, satchels, etc. The shells are often ground very thin, so that colored photographs or designs may be shown through them.

A very interesting series of mounted fresh-water pearls was shown from Wisconsin, Tennessee, Ohio, and Texas. Among these are some absolutely white, pink, and brown pearls. All those from Wisconsin are very fine, possessing a marvelous metallic luster. The pearl fisheries of that State have produced at least $250,000 worth of pearls since 1889.

In the Mining building, Bunde & Upmeyer, of Milwaukee, exhibited a case of several hundred Unio pearls, some of them very fine, of the various colors found in the rivers of Wisconsin.

The New York State exhibit, in the gallery of the Anthropological building, contained a superb collection of Unios, beautifully mounted and well labeled, belonging to the State cabinet. This collection embraces those of the Rev. John Walton, Shelly G. Crump, C. E. Beecher, and others. In the south gallery, forming a portion of the exhibit of Prof. Ward, of Rochester, were some magnificent specimens of Unios. Superb examples of *Dipsas plicatus* Lea, from Lake Riwa and from central China, containing pearl figures of Buddha and flat pearl-like disks, produced by inserting between the mantle and the shell of the mollusk small tin-foil figures of Buddha, or small hemispherical disks, which in time become coated by the pearly nacre, were shown in the folklore collection of G. F. Kunz and in the Ward collection in the south gallery (*see* Pl. 40), both now in the Field Columbian Museum.

This method of producing figures and symbols that could be used for ornaments is one that would recompense any American who would produce the same results in some of our richly colored and brilliantly lined Unios.

CULTIVATION OF THE PEARL OYSTER.

In the Japanese section, K. Mikimoto, of Toba, Shima, Japan, made a remarkably interesting exhibit of pearl shells from the Bay of Ago, province of Shima, on the Pacific coast of central Japan, near the famous temple of Ise. The Bay of Ago is about 3 miles long and 2 miles broad, and, penetrating inland for some distance, its waters are always calm. The pearl oyster is abundant along its shores at a depth of from 1 to 6 fathoms, where the bottom is sandy, with a scant growth of seaweeds.

Little can be ascertained as to when the fishing of pearl oysters began in this bay. It is believed, however, to have commenced some three or four centuries ago.

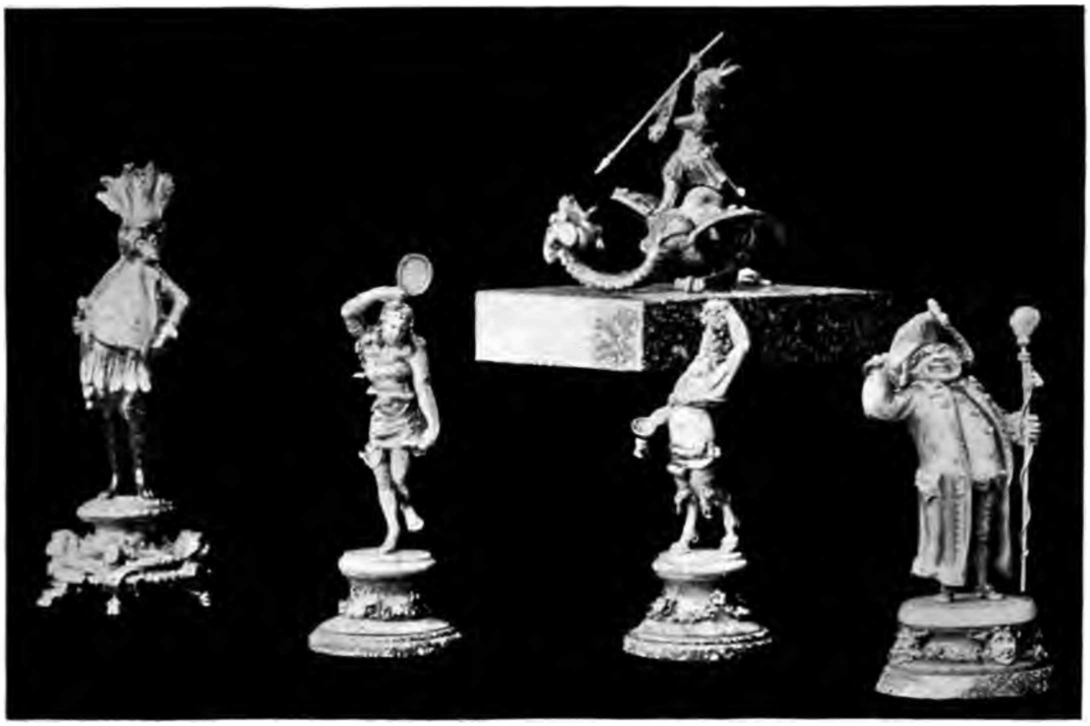
In about 1880, pearl fishing in this bay was very actively carried on, and although pearls were comparatively cheap at that time, the annual yield amounted to $10,000. But too great an activity on the part of fishermen led to a depletion of the fisheries, so that the yield gradually decreased until in 1885 the value of pearls obtained was less than $1,000.

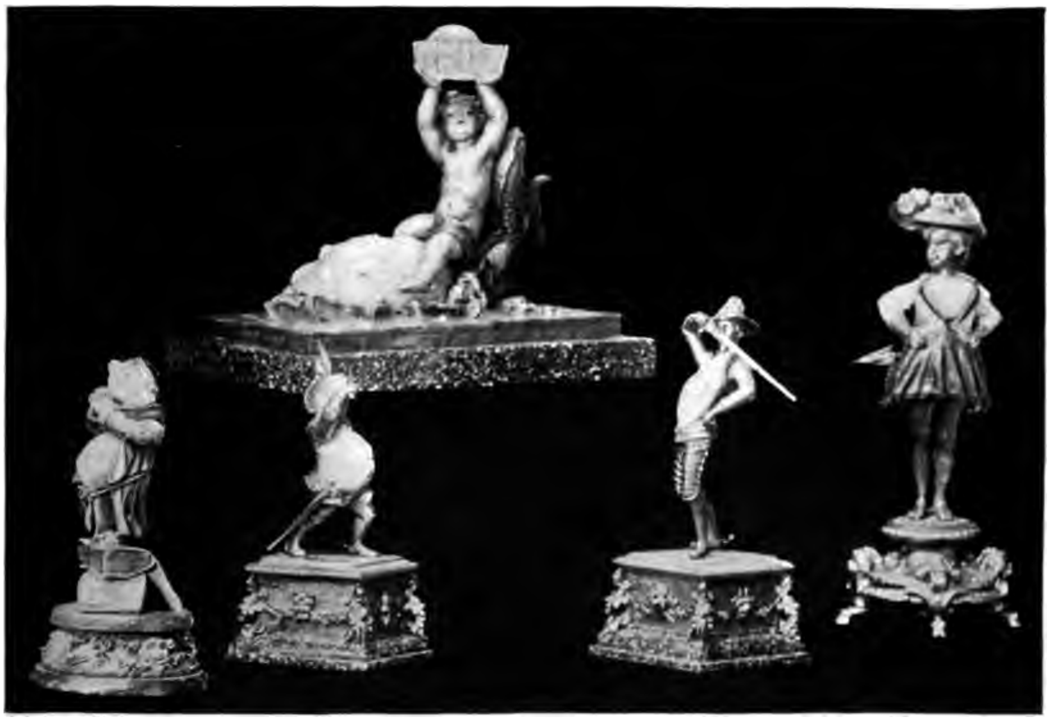
Fearing the extinction of this valuable shellfish, the Fisheries Association of the district took steps to restore the industry by establishing a closed season, etc., and, at the advice of the late Admiral Y. Yanagi, president of the Japan Fisheries Society, of Profs. K. Mitsukuri and C. Saraki, of the Imperial University, and of Kishinouye, the zoologist of the department of agriculture and commerce, tried with success the experiment of collecting and rearing the spat on tiles, stones, logs, ropes, etc. By the adoption of these various means the fishery has largely recovered its lost ground, and for the past two or three years the yield of pearls has been restored to the amount obtained at the active period of the industry. Mr. Mikimoto entertains every hope of greatly extending and promoting the industry in the future by systematic cultivation of this kind.

The chief source of pearls in Japan is the pearl oyster (*Aricula martensii*), but the mussel (*Mytilus crassitesta*), the oyster, the sea-ear or abalone (*Haliotis gigantea*), and the fresh-water pearl mussel (*Dipsas plicatus*) also produce their special pearls. In Japan, as in Europe, pearls from the pearl oyster are especially valued on account of their brilliant luster and pure color. Those with the silvery hue command higher prices than those of the golden hue. Pearls from the mussel, the pearl mussel, etc., are of various tints: those from the oyster are usually milky-white; while those from the sea-ear (Haliotis) and abalone shell have usually a golden tinge.

Mr. Mikimoto's exhibit illustrated the growth of pearl shells from one to nine years. This shellfish spawns from June to August: therefore some of the shells exhibited could not have been more than a few weeks old. These continue to grow until the following November, when the approach of the cold season checks them for a time. In March of the year following, growth again commences, and on this account February is considered the end of the "pearl-oyster year." In other words, young shells collected in the first season, up to and including the following February, are called first-year shells; those obtained from March of the second year to February of the third year are known as second-year shells, etc.

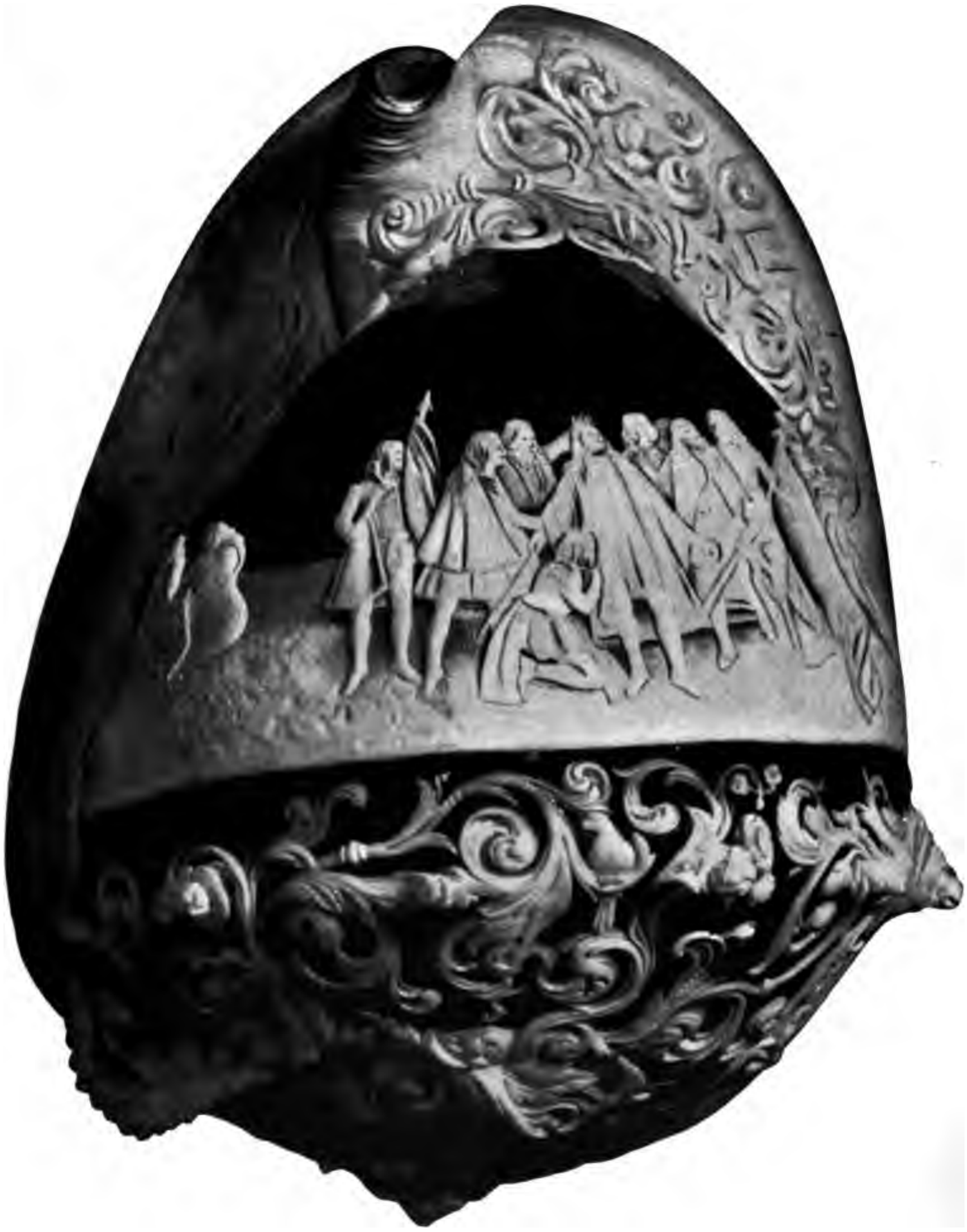
NOTE.—Articles figured on plates 29, 30, 32, 33, 34, 35, 36, 37, 39 (see page 440) are in the Tiffany-Higinbotham Collection in the Field Columbian Museum, Chicago, Illinois.





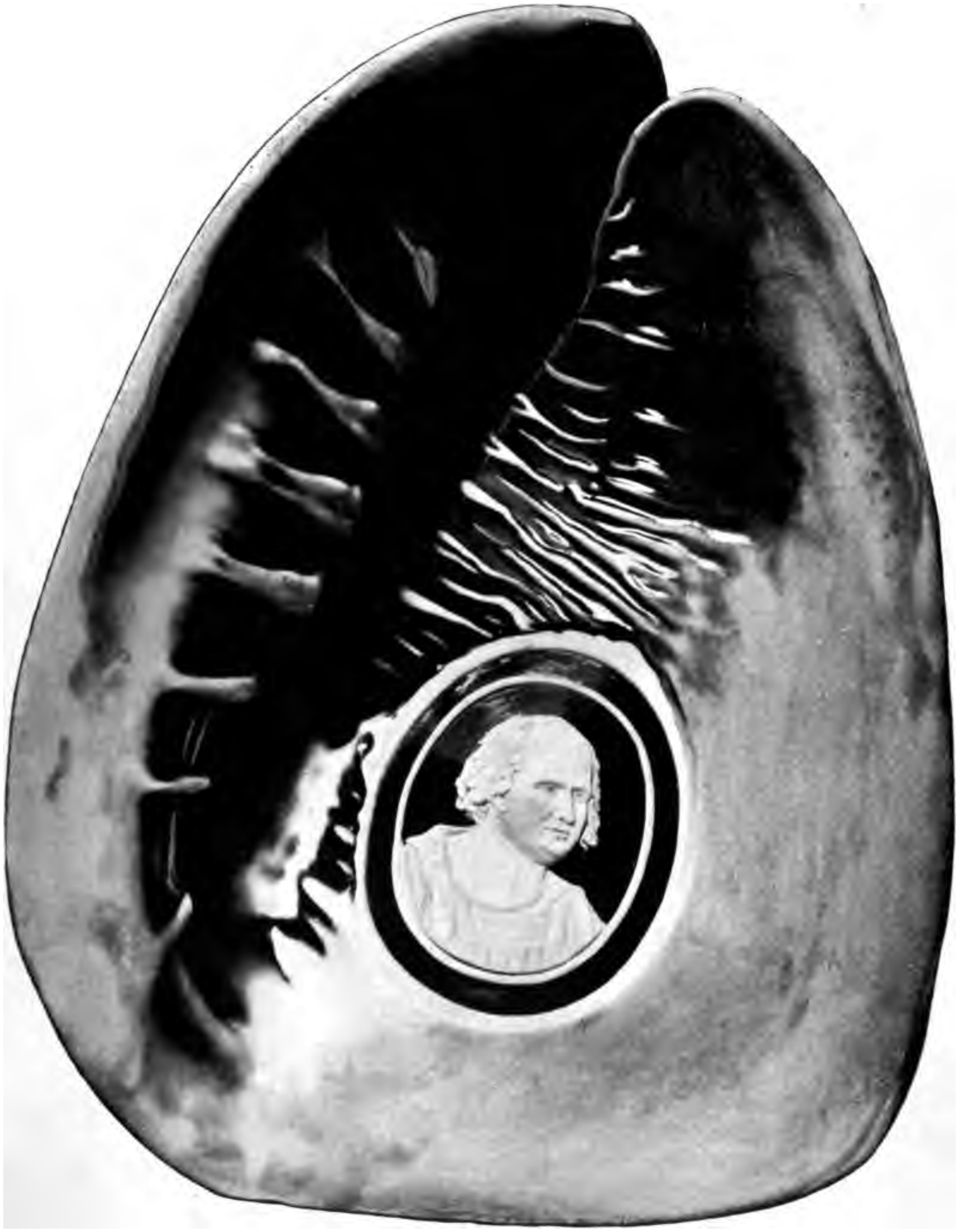
OBJECTS IN SILVER, IN WHICH SOME PART OF THE FIGURE IS MADE OF A LARGE ORIENTAL BAROQUE PEARL.

Exhibited by Richard Horstman, of Berlin, for Messrs Heitel & Sohn, Hanau.

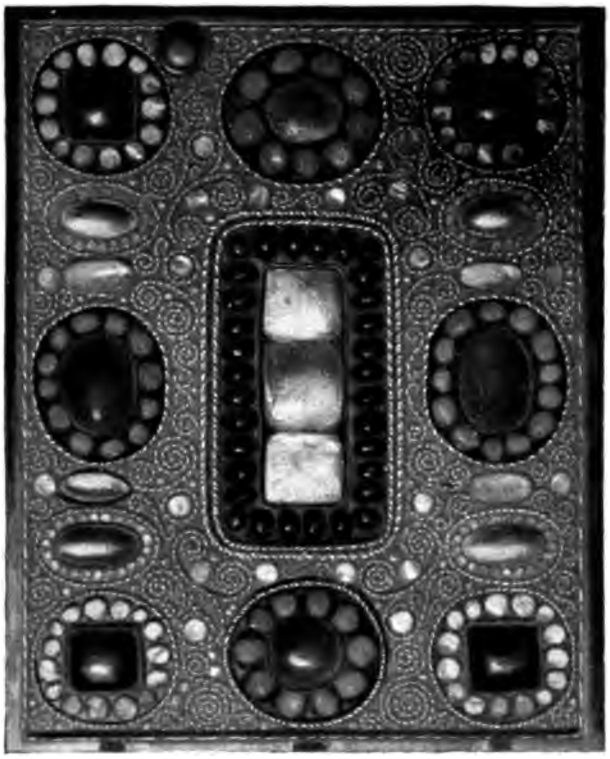


SARDONYX HELMET SHELL REPRESENTING THE LANDING OF COLUMBUS, A COPY OF THE BAS RELIEF ON THE MONUMENT TO CHRISTOPHER COLUMBUS IN NEW YORK.

Carved by E. Campi, of Rome, who obtained the award at Rome for this fine carved cameo-shell. This shell is unique, and will not be reproduced. Owned by Gardiner G. Hubbard, Esq., Washington, D. C.

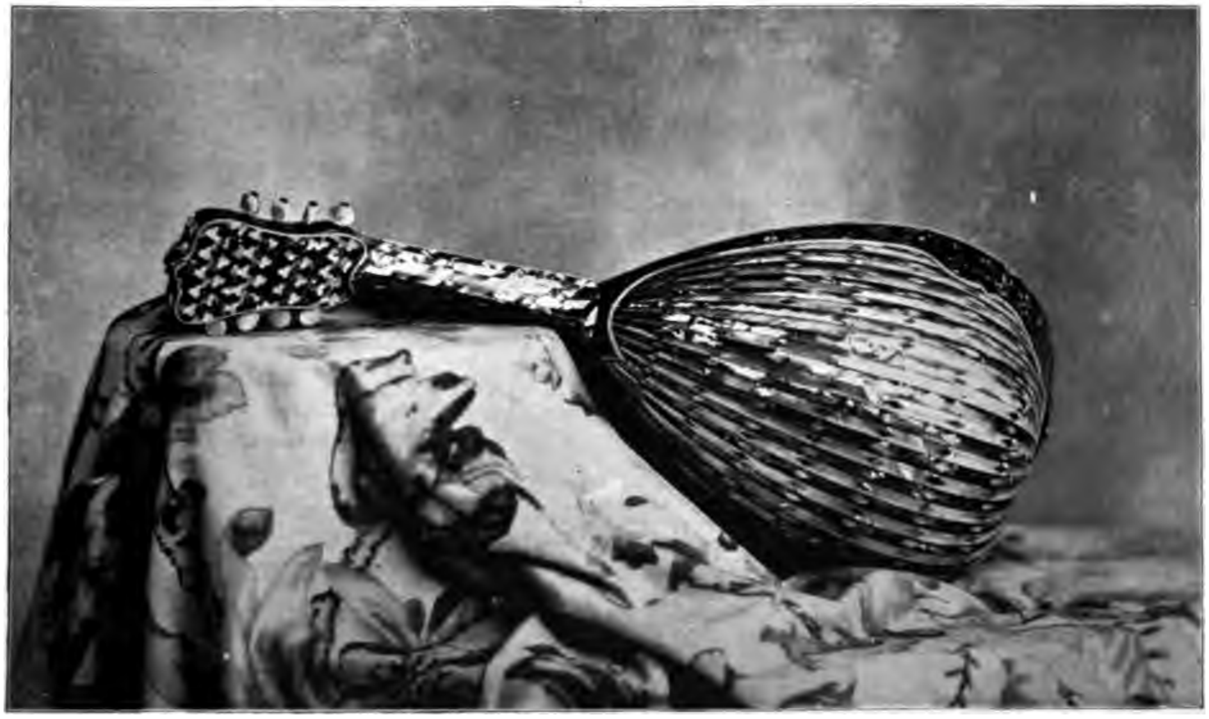


SARDONYX HELMET SHELL, REVERSE. PORTRAIT OF COLUMBUS.



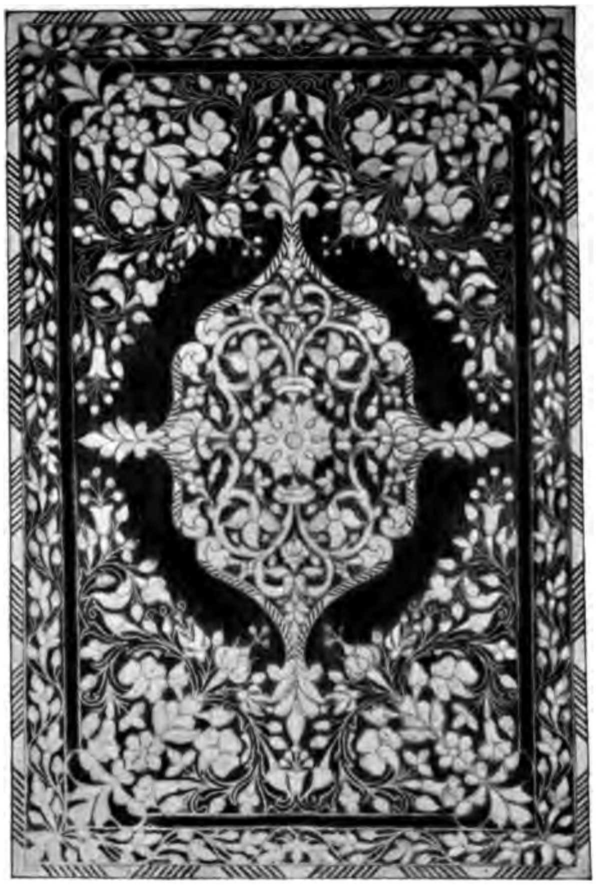
TABERNACLE DOOR, TIFFANY GLASS AND DECORATING COMPANY.

Three center pieces in central ornament and four circles at each end, natural pearly pieces of mother-of-pearl; four oblong ornaments above and below circles, rounded *Nautilus pompilius*; four other circles with oblong or irregular centers, natural beach pebbles, used for translucent effect—an original use of natural objects.



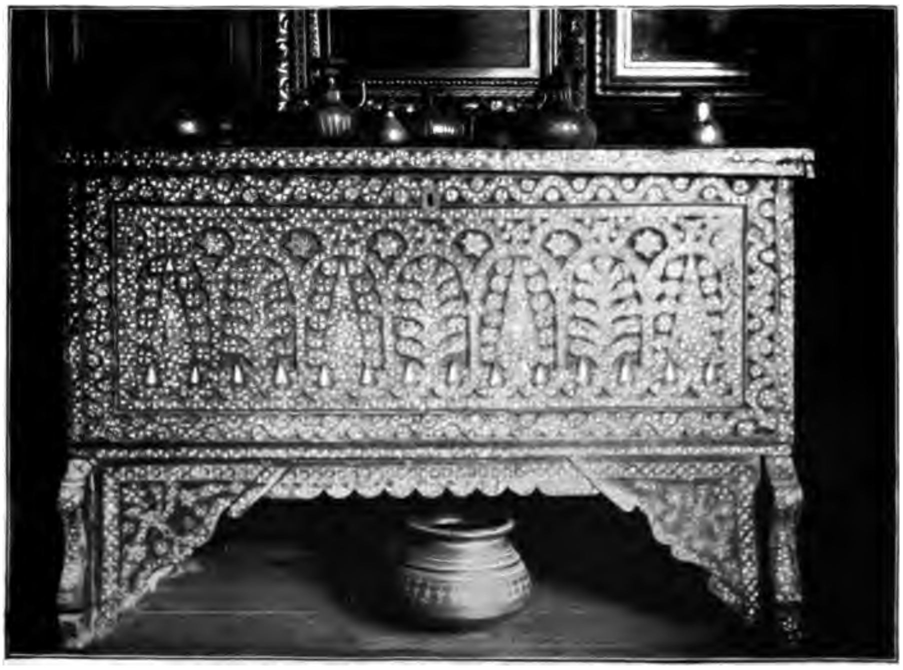
MANDOLIN, LYON & HEALY, CHICAGO.

Made of two thousand separate pieces of various materials, including four distinct qualities of pearls, the effects being produced by the shading of the different pearls.



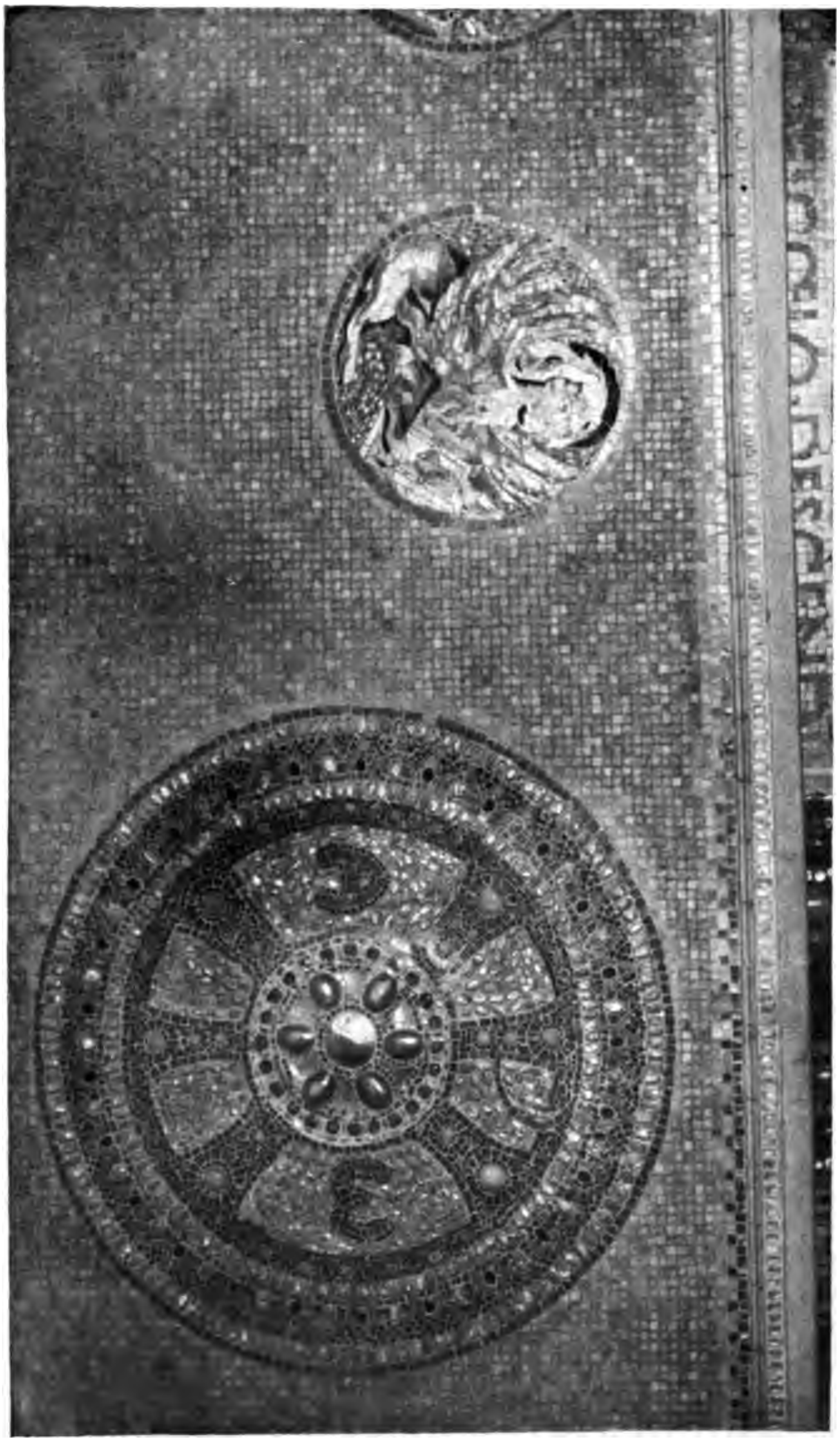
OAK SCREEN INLAID WITH MOTHER-OF PEARL. ONE-TENTH DIAMETER.

Damascus work, made for World's Columbian Exposition by Lockwood De Forest New York



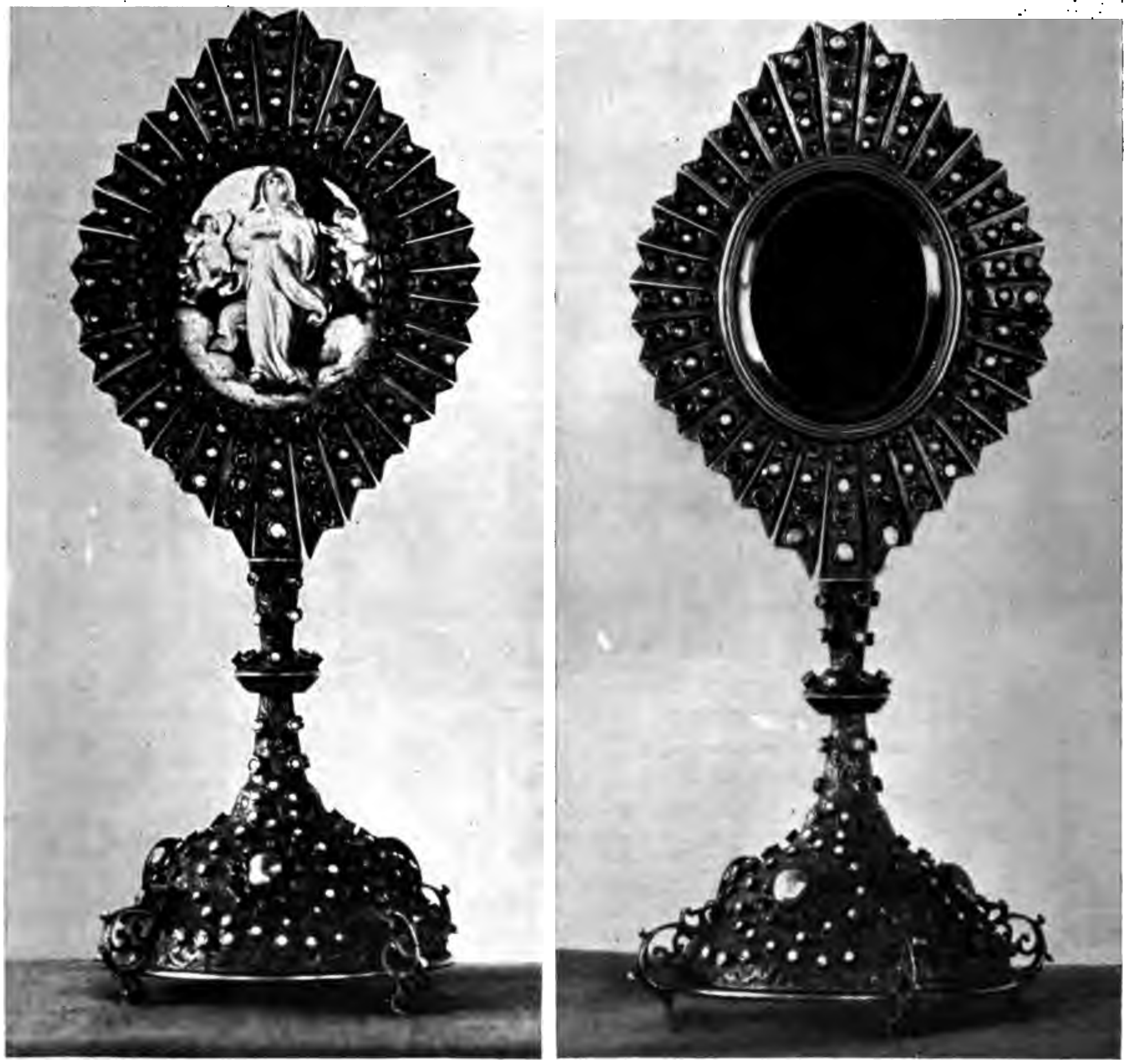
OLD WOOD CHEST, INLAID WITH MOTHER-OF-PEARL. ONE-NINTH DIAMETER.

Damascus work, 75 years old Exhibited by Lockwood De Forest, New York



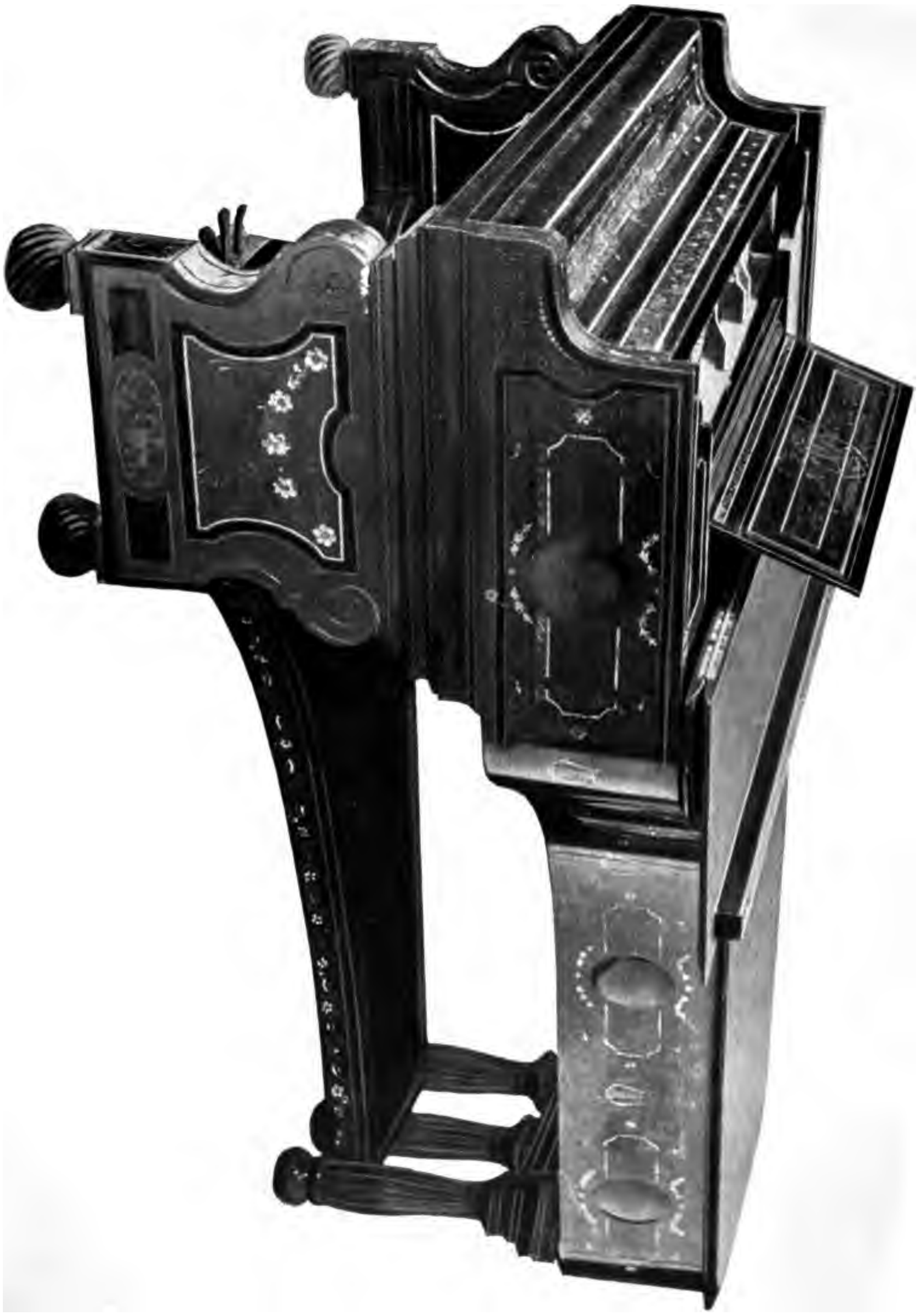
FRONT OF MENSA, TIFFANY GLASS AND DECORATING COMPANY.

Mother-of-pearl (natural, rounded, pearl-like surfaces) used in upper border-line and in circles on right. *Nautilus pompilius*, natural rounded pieces, used for central ornament of large circle. Groundwork, a mosaic of Mexican onyx, colored and aventurine glass. Chicago, 1893.



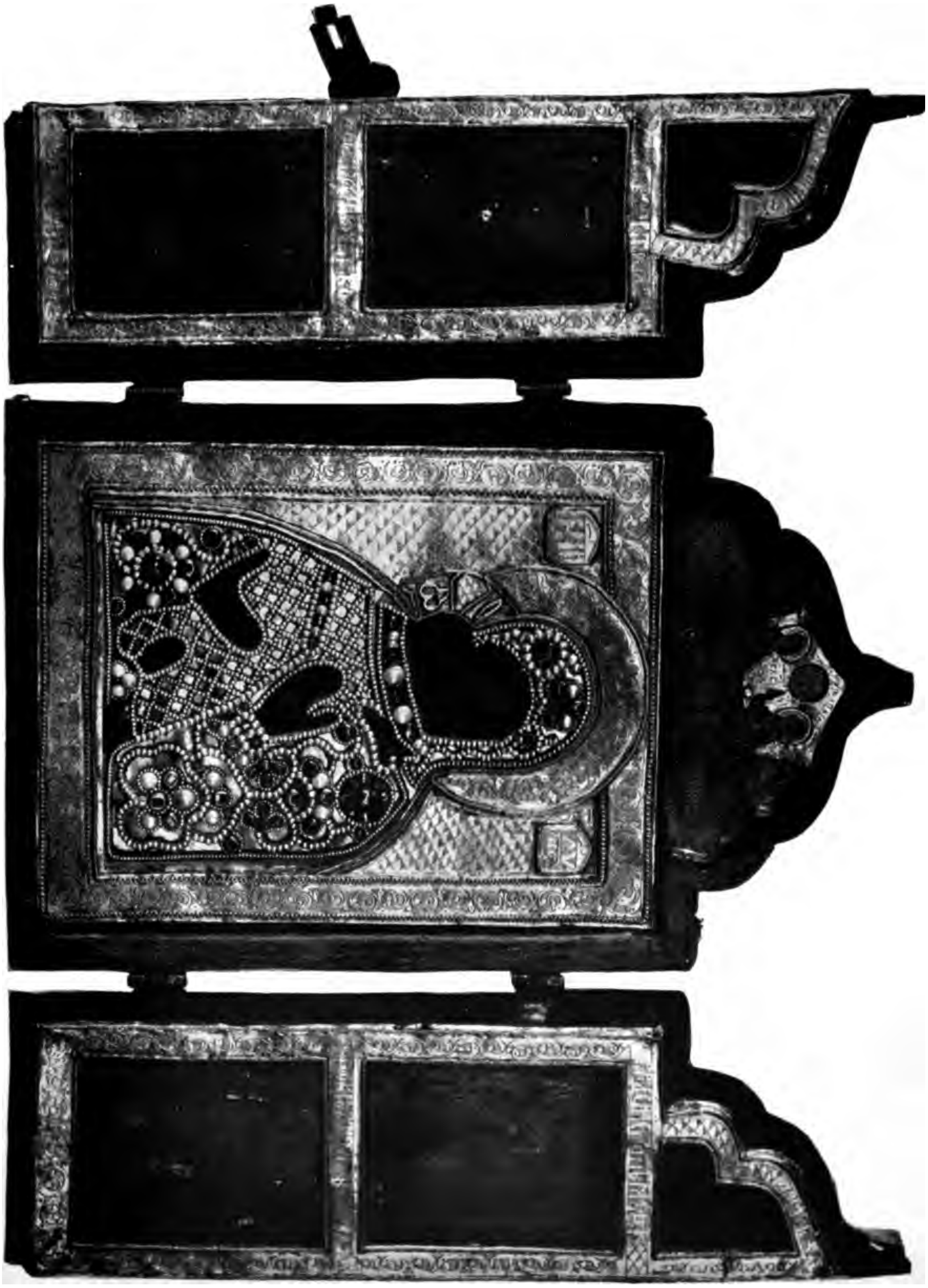
SILVER RELIQUAIRE

Rococo style. Bohemian work of the seventeenth century, inlaid with Bohemian river pearls, garnets, and turquoises. Rock crystal cover over relic. Limoges enamel on reverse side.



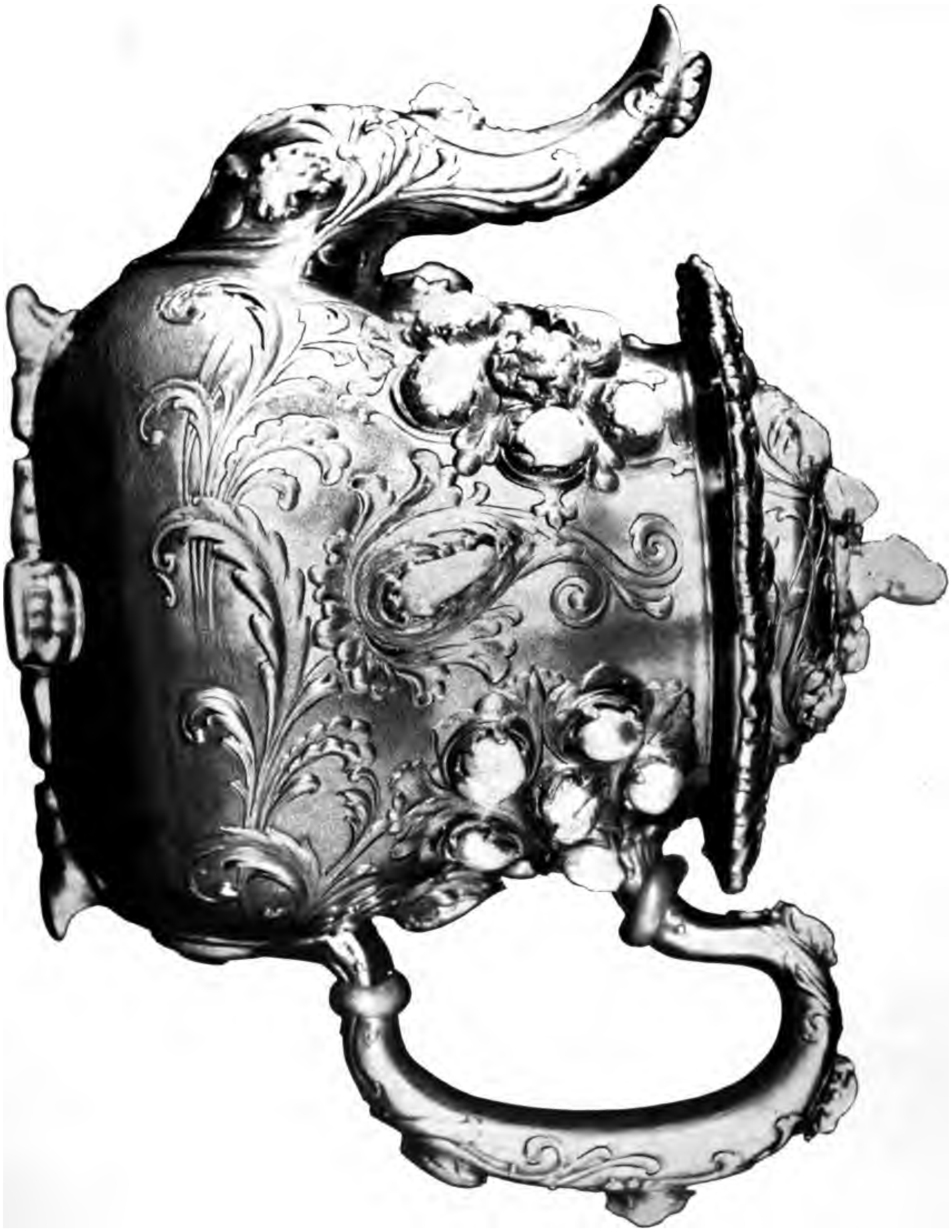
GRAND PIANO, COTTIER & CO.

One of the most remarkable examples of American pearl inlaying; a study of the old Spanish method of inlaying mother-of-pearl with tortoise shell and colored woods in a hard wood.



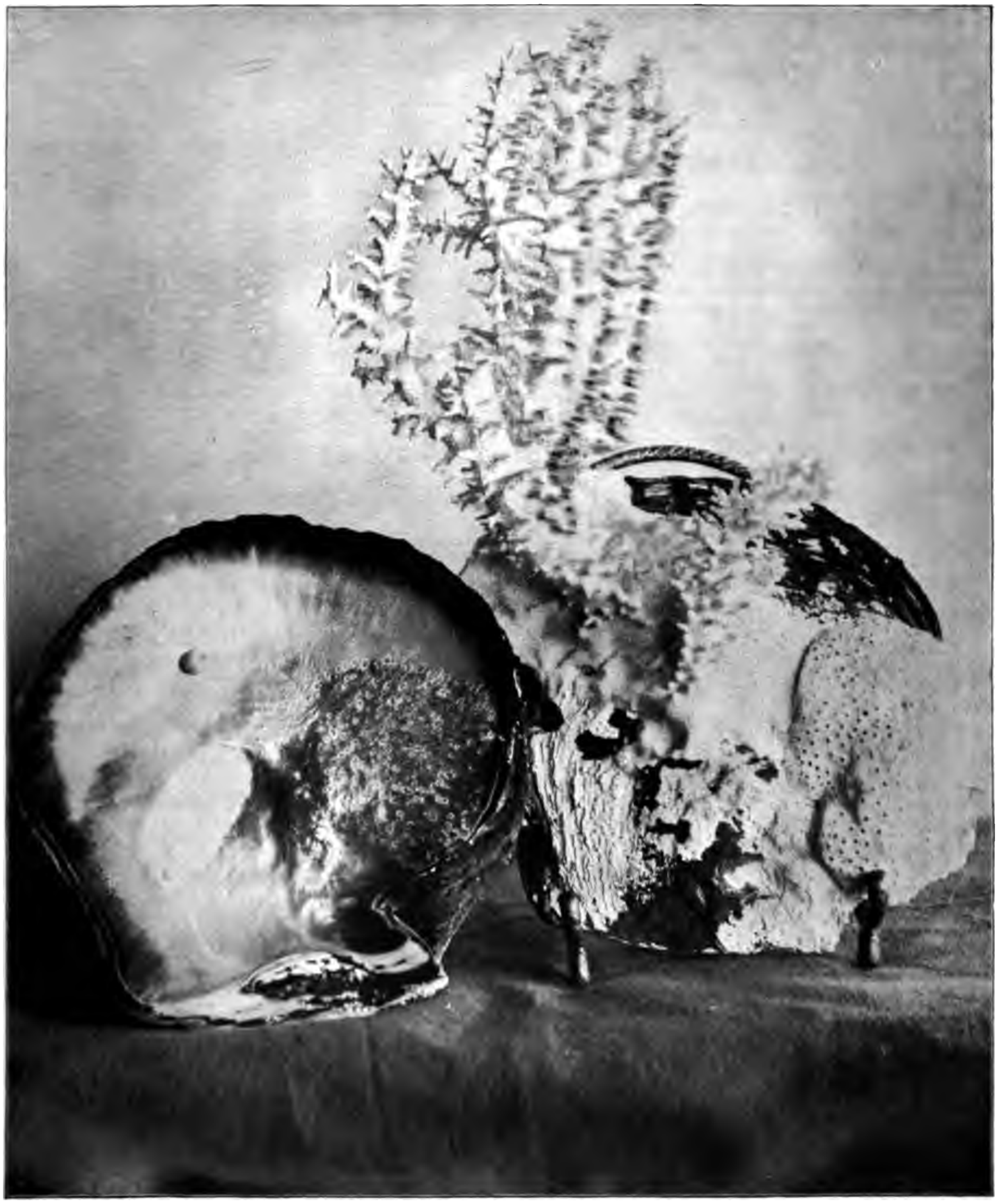
RUSSIAN ICON. TRYPTICH OF VIRGIN AND CHILD.

Made about 1640, by a leading Russian artist, for one of the principal churches of Nijni Novgorod. The framework in silver gilt; the inlaying, river pearls, rubies, emeralds, etc. Brought from Nijni Novgorod by George F. Kunz, in the collection of the United States National Museum, Washington, D. C.



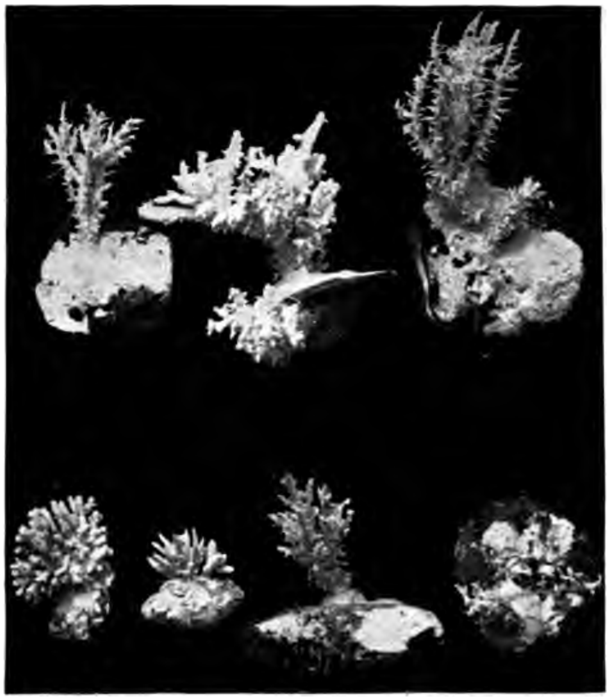
STERLING SILVER TEAPOT.

Gilt, encrusted with baroque pearls from the rivers of Tennessee. Made by Tiffany & Co.



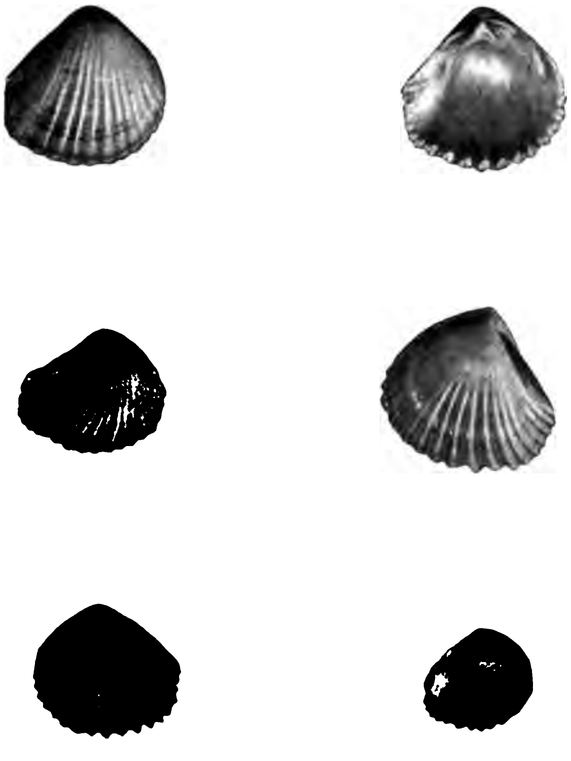
PEARL OYSTER, *Meleagrina margaritifera*. OBVERSE AND REVERSE, INNER AND OUTER VALVES.

On the exterior are groups of three different species of coral. Size, valve with coral, 15 inches high 7 inches wide.

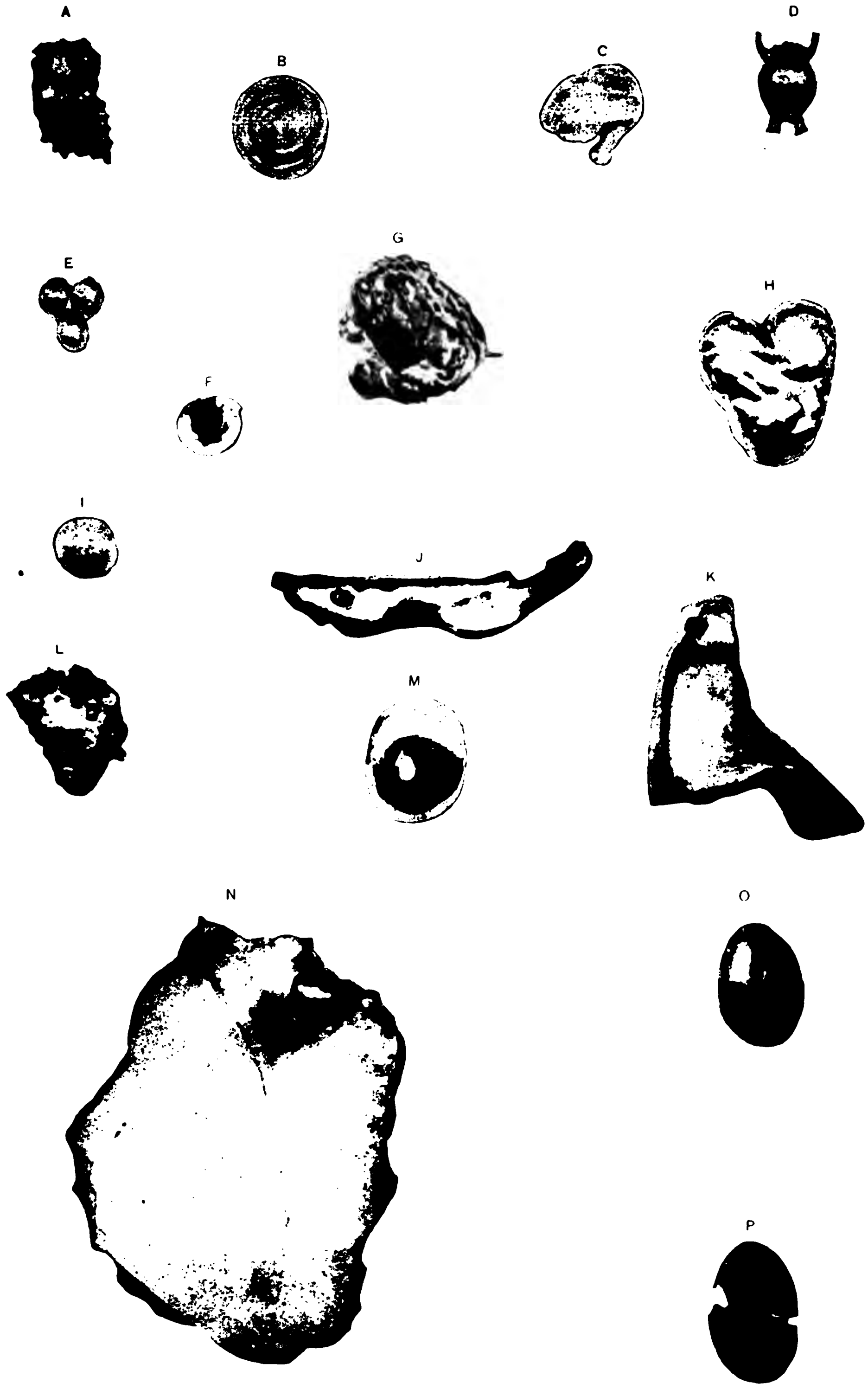


PEARL OYSTER SHELLS WITH CORAL GROWTHS.

One-tenth diameter, from Tahiti



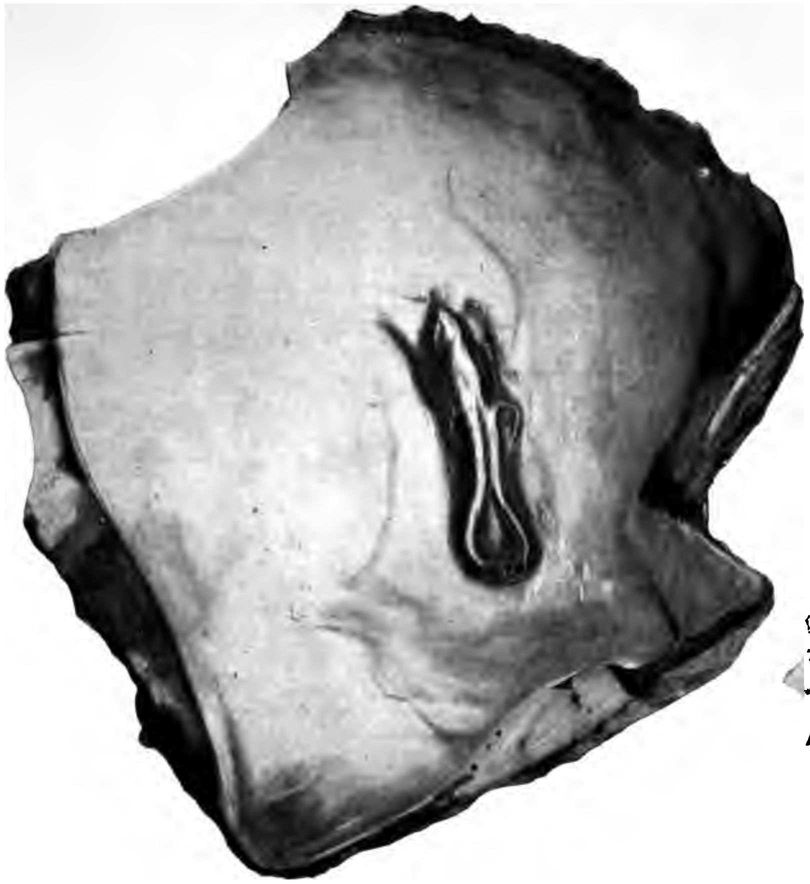
TRIGONIA PECTINATA. Australia. Natural size.



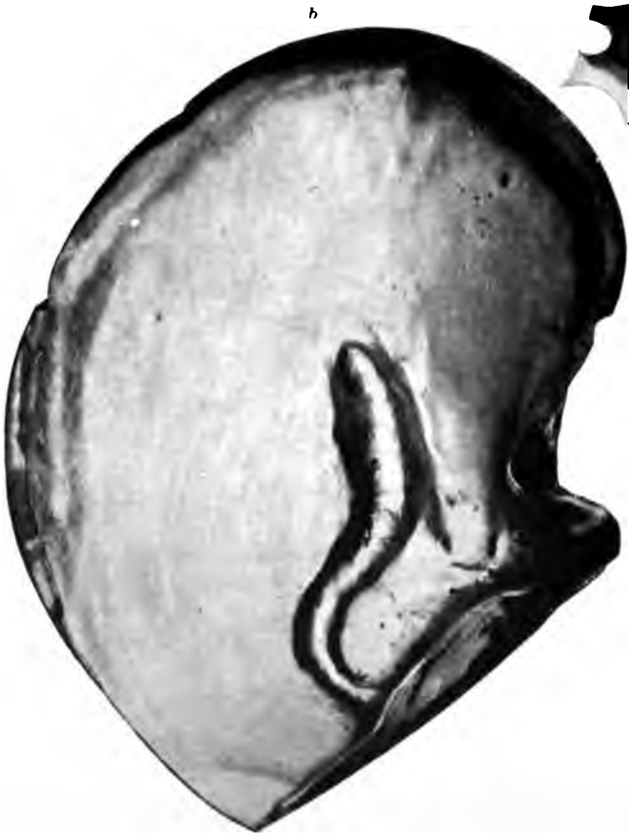
TIFFANY-HIGINBOTHAM COLLECTION.

(A) Fresh-water pearl, simulating Pan playing on pipes, pink.
(B) Fresh-water pearl, showing concentric markings.
(C) Fresh-water pearl, animal head; white.
(D) Fresh-water pearl, ram's head; bronze color.
(E) Four pearls united, representing head; from Tahiti.
(F) Ostrea borealis, showing internal structure.
(G) Fresh-water pearl, Spaniel Head. ruddy copper color.
(H) Heart-shaped pearl.
(I) Ostrea borealis.
(J) Greenish pearl, ***Haliotis rufescens.*** Lower California.
(K) Greenish pearl from a large species of Trochus. West coast of Mexico.
(L) Pink Unio pearl. Tennessee.
(M) Ostrea borealis, resembling human eye.
(N) Fragment of Unio from Wisconsin; copper colored.
(O) Oriental pearl; peeled. Exterior convex side.
(P) Interior concave view.

a

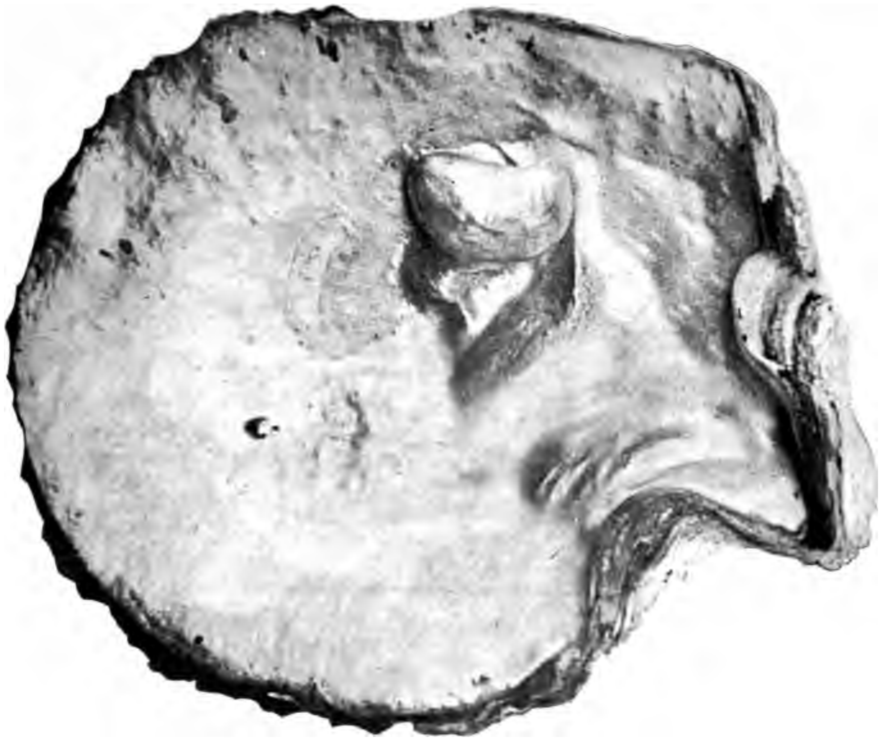


b

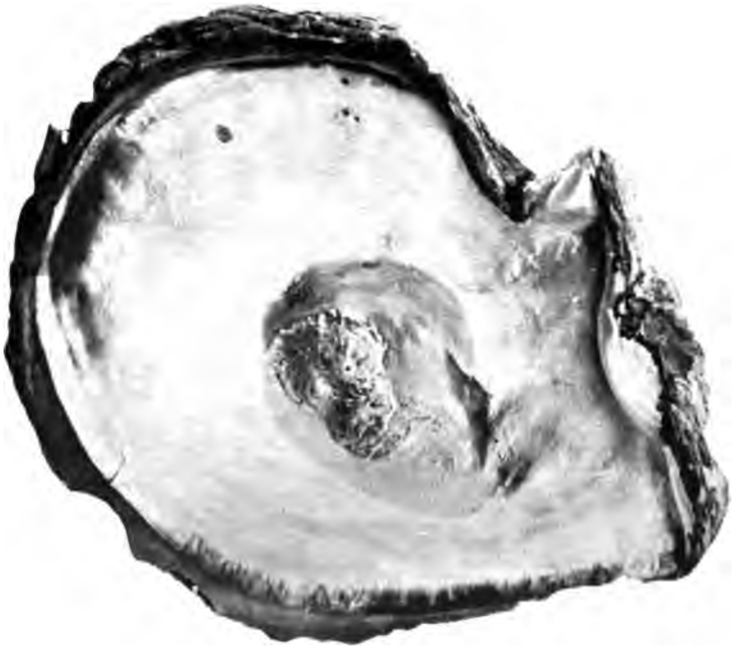


(a) MELEAGRINA MARGARITIFERA, WITH INCLUDED PARASITIC FISH. Lower California.

(b) MELEAGRINA MARGARITIFERA, WITH INCLUDED PARASITIC FISH. Lower California.

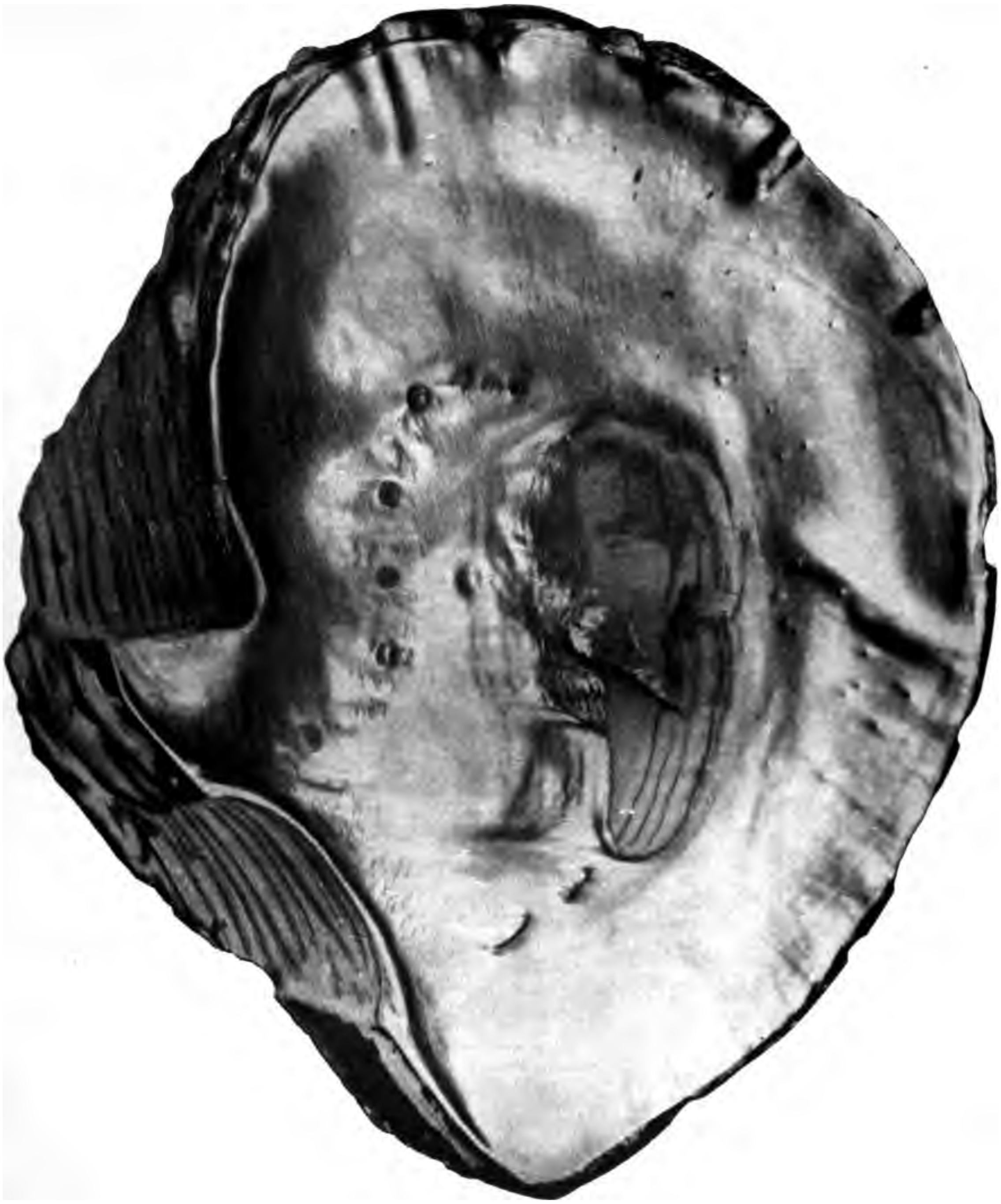


PEARLY KNOB. *Meleagrina margaritifera.* Six by five and a half inches Thursday Island, Tahiti.



MOTHER-OF-PEARL SHELL WITH PEARLY KNOB WITH MONKEY-LIKE FACE

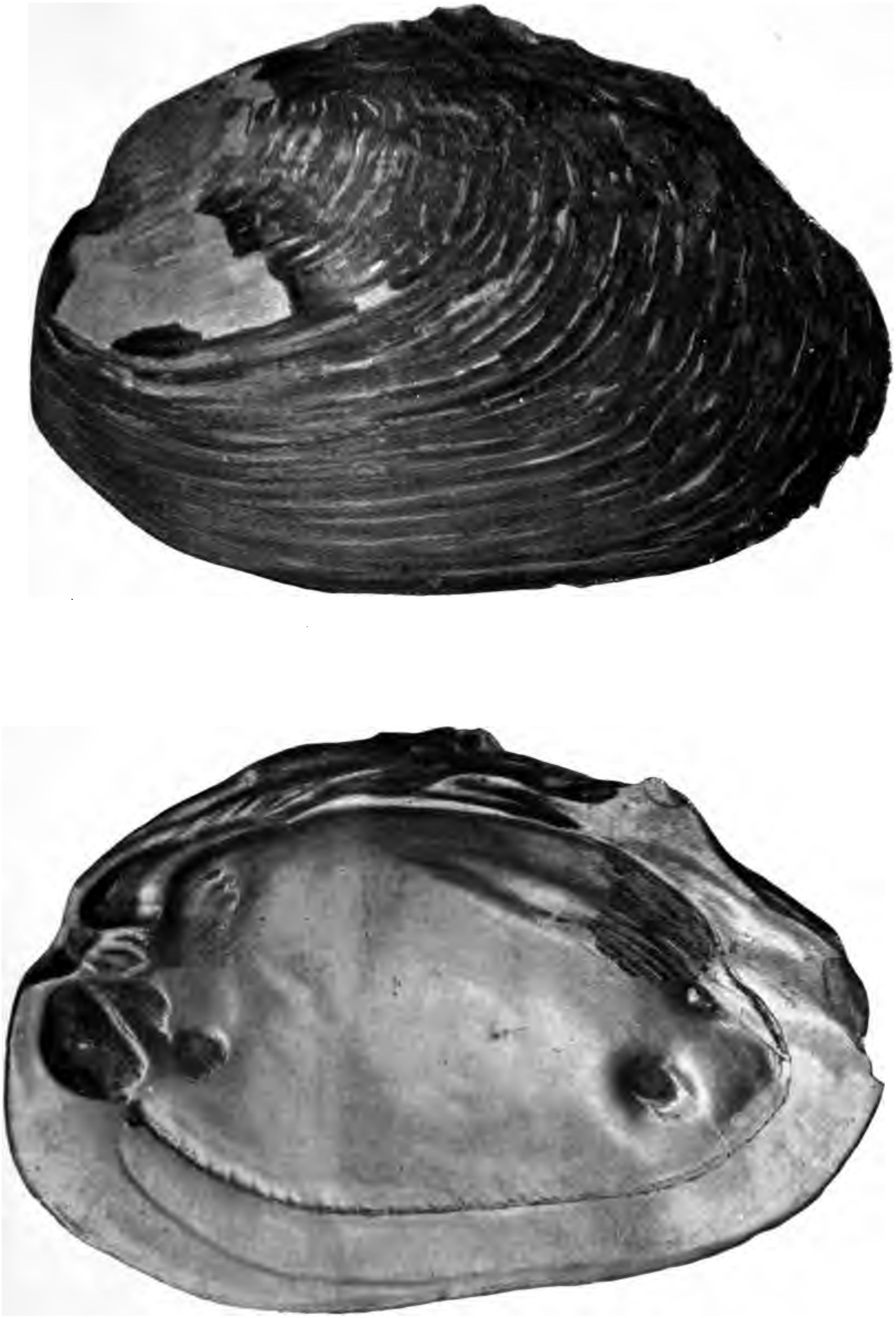
Four and a half by four and a half inches. Thursday Island, Tahiti.



PEARL OYSTER.

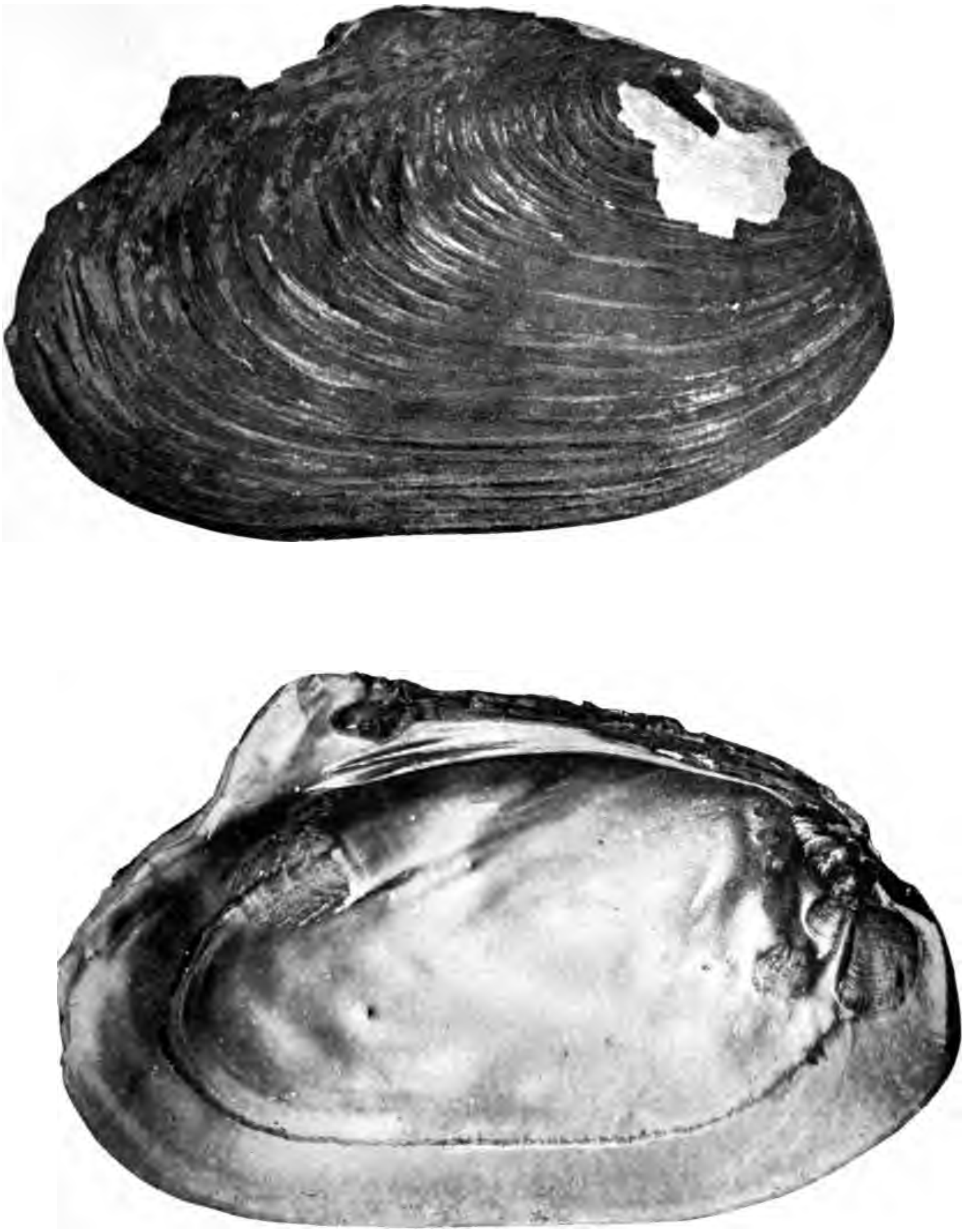
One valve showing two ingrowing pearls and four places where pearls had been attached and had fallen out. Coast of West Australia.

PLATE 35.



FRESH-WATER MUSSEL, UNIO, WITH DEEP PURPLISH-RED INTERIOR.

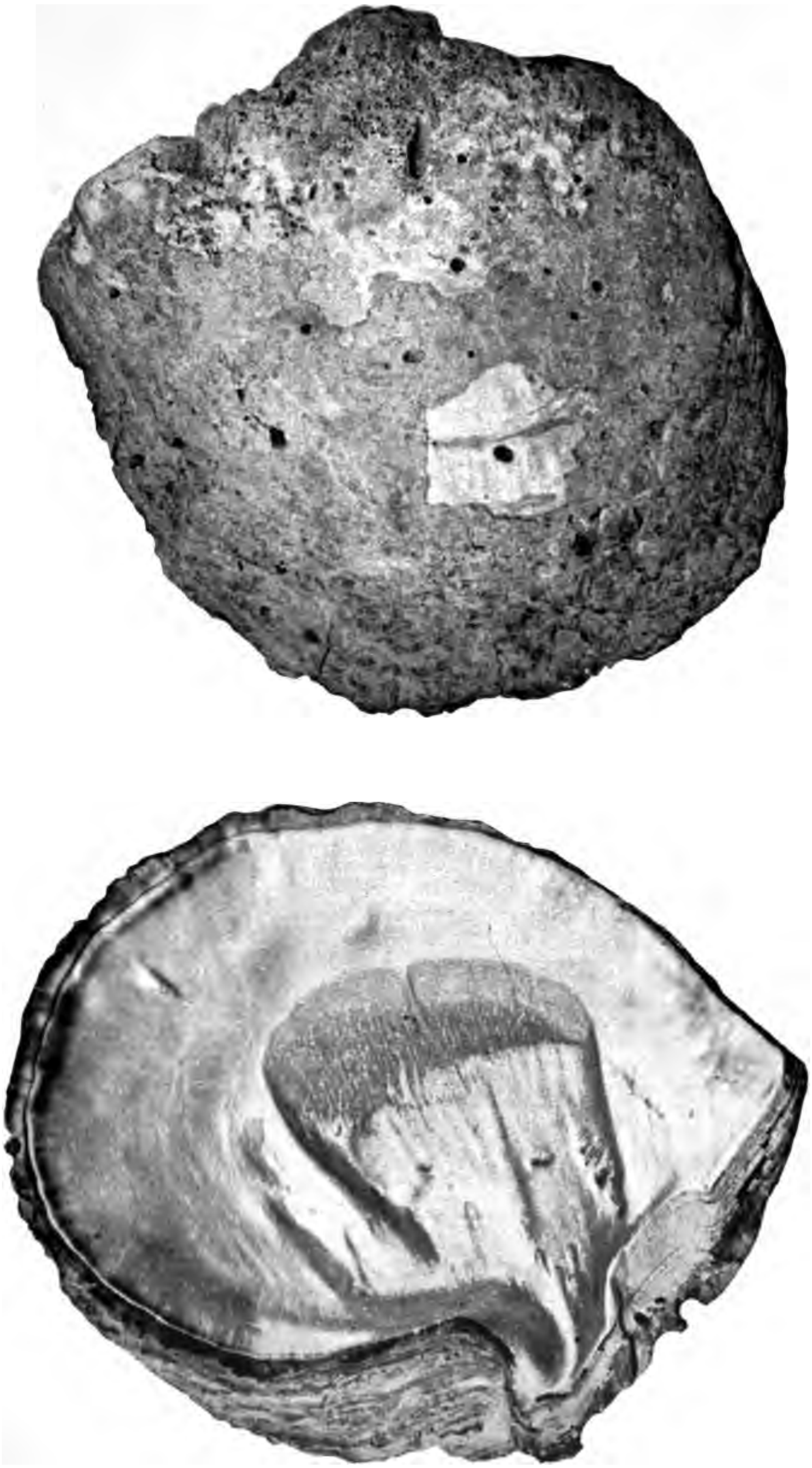
Eight inches long. From Sugar River, Wisconsin.



FRESH-WATER MUSSEL, UNIO, DEEP PURPLISH-RED INTERIOR

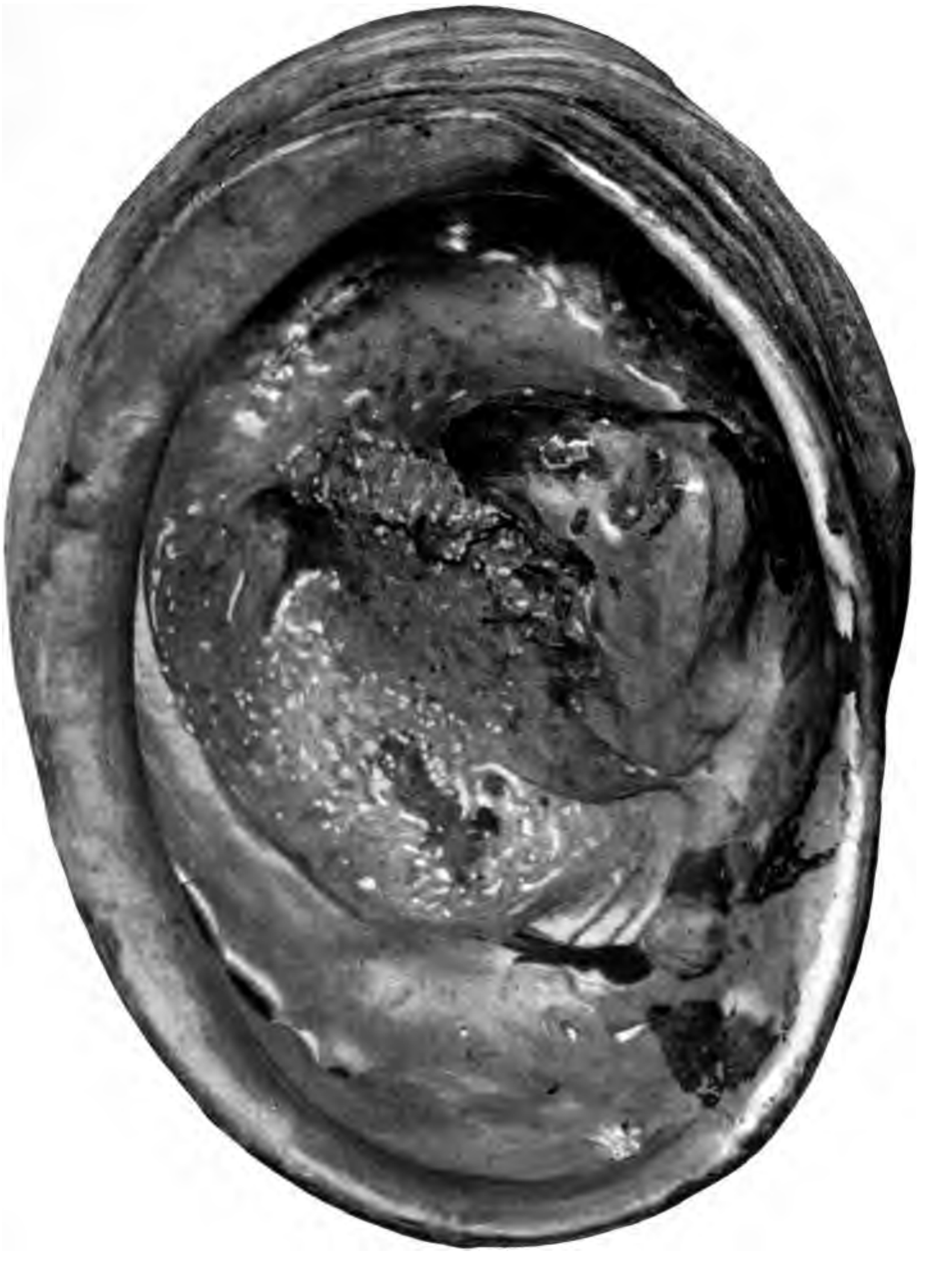
Eight inches in length. Sugar River, Wisconsin

PLATE 37.



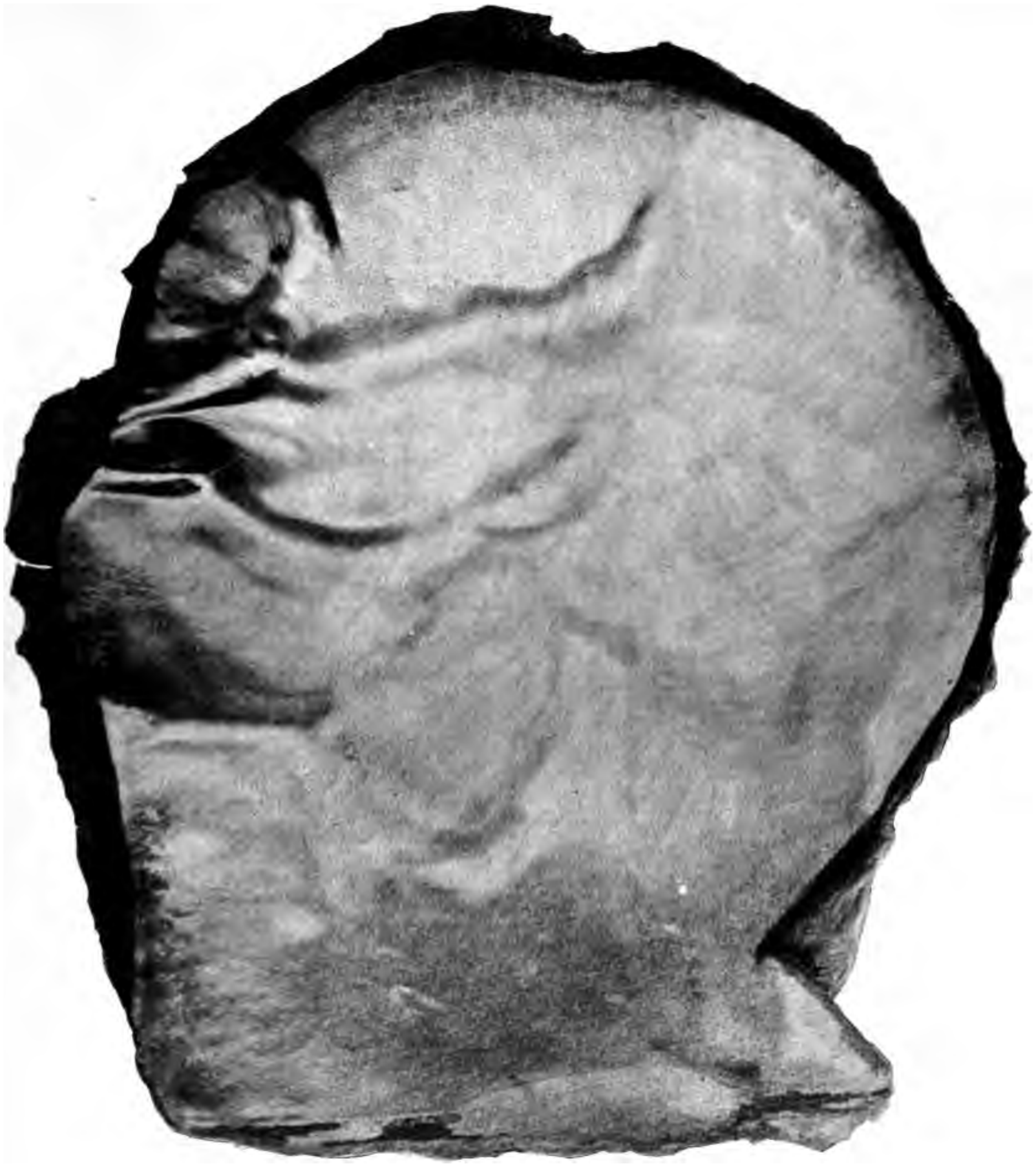
PAIR OF LARGE SHELLS, *Meleagrina margaritifera*, MOTHER-OF-PEARL

Weight, 155½ ounces, each valve being 11½ inches across.



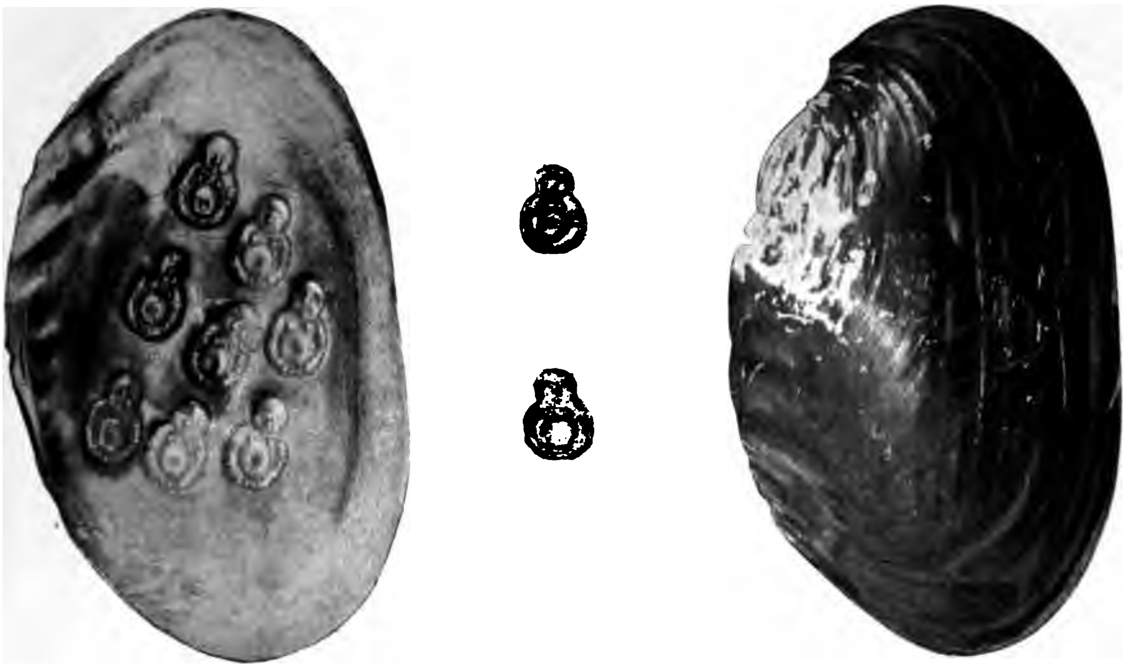
ABALONE SHELL, *Haliotis rufescens*, WITH PEARLY GROWTH RESEMBLING CAMEL'S HEAD, AND NEARLY TWO INCHES IN DIAMETER.

From coast near San Diego County, California.



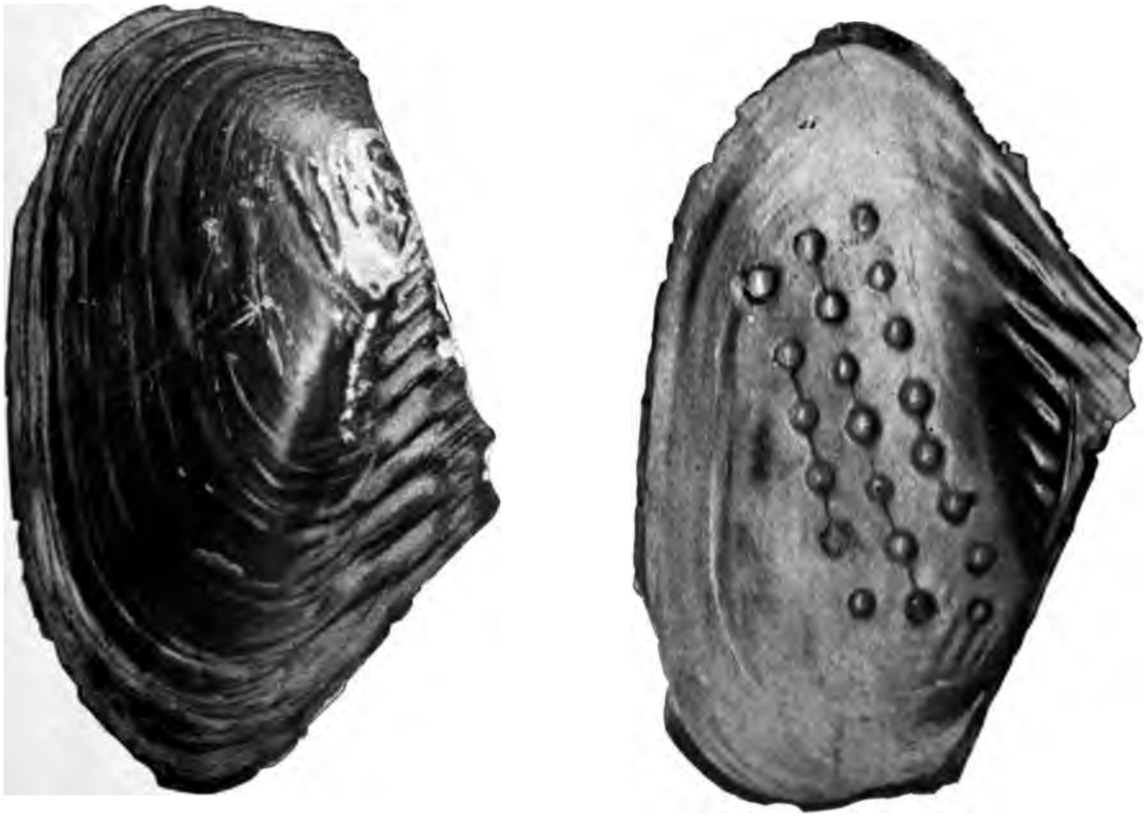
PEARL OYSTER, *Meleagrina margaritifera*, SHOWING BORINGS WHICH THE SHELL HAS COVERED

Six by five inches. Tahiti.



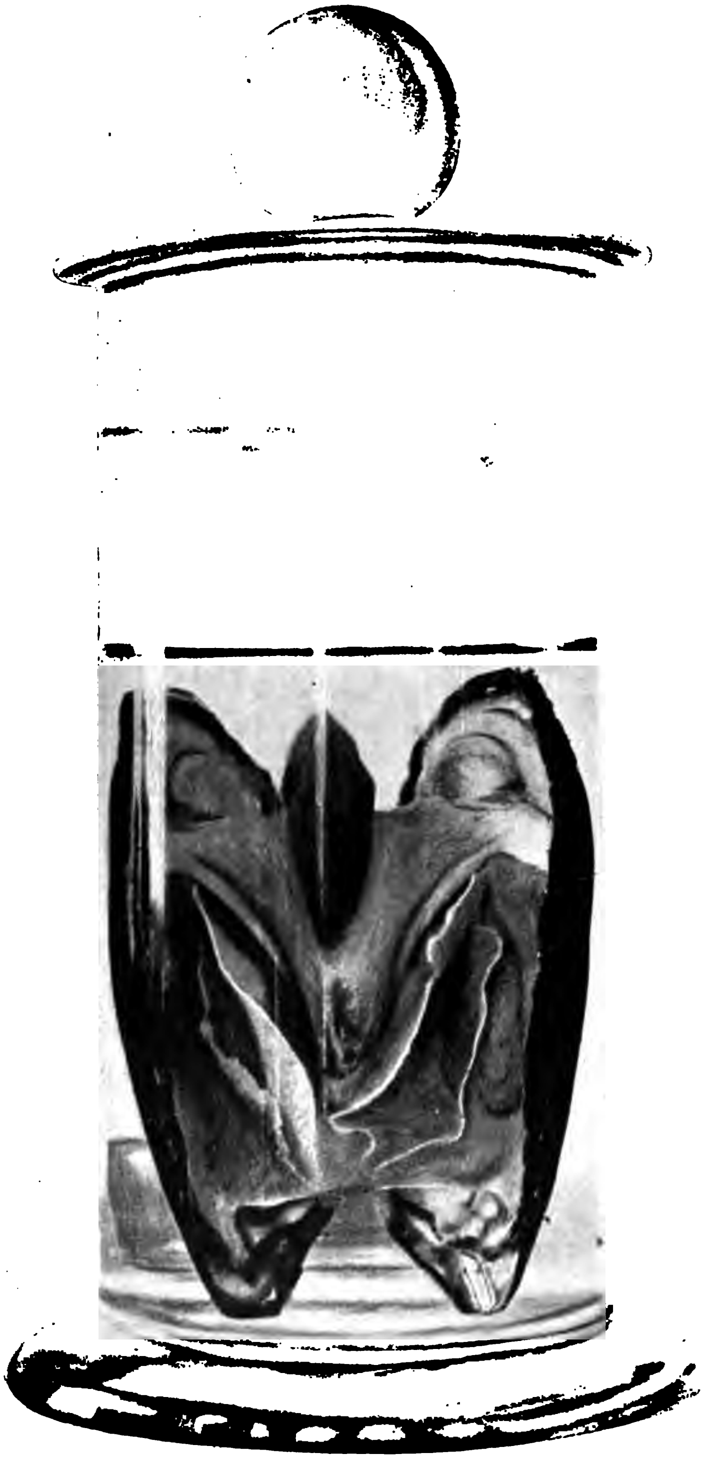
DIPSAS PLICATUS, INTERIOR AND EXTERIOR INTERIOR CONTAINING TINFOIL FIGURES OF BUDDHA.

Four inches long. Pearl-coated figure of Buddha, obverse and reverse, showing concave depression originally filled with tinfoil or wax.



DIPSAS PLICATUS, CONTAINING THREE STRINGS OF BEADS WITH A PEARLY COATING.

Both from temples in Souchow, China.



FRESH WATER MUSSEL, *Margaritana margaritifera*, SHOWING PEARL INCLUDED BETWEEN MANTLE AND SHELL, IN THE LOWER RIGHT-HAND CORNER.

Specimen prepared by V Fric, of Prague From Botova River, Bohemia.

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